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SOCIO-ECOLOGICAL RESILIENCE OF A SMALL-SCALE HILSA SHAD (TENUALOSA ILISHA) FISHERY IN THE GANGETIC RIVER SYSTEMS OF BANGLADESH

Mohammad Mojibul Hoque Mozumder

ACADEMIC DISSERTATION

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Cover picture: A photography taken by Mohammad Mozumder, shows a typical hilsa boat with hilsa fishers in the Meghna River, Chandpur, Bangladesh.

Author's present address:
Faculty of Biological and Environmental Sciences
P.O. Box 64
FI-00014 University of Helsinki
E-mail: mohammad.mozumder@helsinki.fi

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Supervisors
Dr. Aili Pyhälä, Adjunct Professor,
Development Studies, Faculty of Social Science,
University of Helsinki, Finland

Dr. Kristina Lindström, Professor,
Faculty of Biological and Environmental Science,
University of Helsinki, Finland

Advisory Committee
Dr. Laura Uusitalo, Docent, Leading researcher,
Programme for Environmental Information,
Finnish Environment Institute, Helsinki, Finland.

Dr. Soile Oinonen, Docent, Development manager,
Finnish Environment Institute, Helsinki, Finland

Pre-examiners
Dr. Iago Mosqueira Sanchez, Researcher,
Wageningen Marine Research, Wageningen University, Netherlands.

Dr. Heli Saarikoski, Senior researcher,
Finnish Environment Institute (SYKE), Helsinki, Finland

Opponent
Dr. Juha Hiedanpää, Research Professor,
Natural Resources Institute Finland (LUKE),Turku, Finland

Custos
Dr. Sakari Kuikka, Professor,
Ecosystems and Environment Research Programme,
University of Helsinki, Finland

Grading Committee
Dr. Jyrki Lappalainen, Lecturer,
Faculty of Biological and Environmental Sciences,
University of Helsinki, Finland

ABSTRACT

This doctoral dissertation takes a qualitative case study approach to investigate the social-ecological resilience of a small-scale fishery. The research focuses on small-scale hilsa shad fishery of Bangladesh, intending to contribute valuable information to the global project of sustainable natural resource management. This dissertation's primary goal is to provide state-of-the-art knowledge regarding the status of small-scale hilsa fisheries in Bangladesh, including existing management practices, their constraints, and challenges, as well as highlighting the potential and prospects for co-management as one possible means of enhancing social and ecological resilience. The dissertation is comprised of three original research articles, through which I seek to: (i) understand the social-ecological challenges of a small-scale fishery (article I); (ii) investigate the dynamics of, and needs for enhancing, social resilience of coastal fishing communities, including the implications of over-fishing (article II); and (iii) analyze governance and power dynamics that are considered essential for managing a small-scale fishery sustainably (article III). This dissertation draws on theories of social-ecological systems (SESs), driver-pressure-state-impact-response (DPSIR), social-ecological resilience (particularly social resilience), the power cube, and co-management as analytical frameworks. The dissertation's main findings are presented according to the key issues addressed in each article as follows.

(i) Understanding the social-ecological resilience of a small scale fishery: The study shows that the main driving forces causing decreased catches for fishers are the use of illegal fishing gear, overpopulation in the coastal areas, overfishing, the harvesting of juveniles, river water pollution, climate change, upstream dam construction, and cross-border smuggling of hilsa. All these factors compromise sustainable management strategies and have led to disincentives for compliance and increased pressures on hilsa fishery. These pressures include habitat destruction and biodiversity loss, which in turn result in a reduced hilsa catch, poverty, malnutrition, stakeholder conflicts, insecurity, and social tensions. To address these challenges, multilevel responses are recommended for ensuring the sustainability of hilsa fishery, including enhancing the social resilience of the fishing community, increasing incentives for compliance for all fishers and major stakeholders at the ground level to support hilsa conservation, promoting community-supported fisheries, improving financing mechanisms for the fishers, and introducing hilsa-fishing-based eco-tourism.

(ii) Enhancing the social resilience of the coastal fishing communities: The findings of the study reveal that while the establishment of hilsa sanctuaries

has improved the previously low ecological sustainability of local small-scale fishing, the current hilsa fishery management challenges the social resilience of hilsa fishers by creating new inequalities in the distribution of power and privilege, particularly in terms of how seasonal fishing bans are enforced and compensation distributed for income lost during the fishing ban periods. Based on these findings, specific measures are suggested to strengthen social resilience at the local level, including building community networks, developing community infrastructures, updating existing rules and regulations, providing alternative means of generating income for fishers during low-catch periods (natural disasters or fishing bans), and more active sharing of responsibility between stakeholders and government for management of hilsa fishery. These findings also stress the need to move beyond top-down rules and regulations to a system of co-management to improve social resilience among resource-dependent communities.

(iii) Governance and power dynamics in a small-scale fishery: The analysis here displays an imbalance in the present hilsa fishery governance structure, with some stakeholders exercising more power than others, sidelining fishers, and encouraging more non-compliance in terms of illegal fishing that ultimately harms both fishery and its users. To overcome this issue, a co-management system is proposed as essential for dealing with the power asymmetry among hilsa fishery stakeholders to ensure effective hilsa fishery governance. The results of this study suggest that the recognition of analyzed power dynamics has substantial implications for the planning and implementation of co-management regimes and the long-term sustainability of hilsa fishery.

Using the DPSIR framework, the findings of this dissertation bring forth the cause–effect interactions between human pressures and environmental components and thus contribute valuable knowledge for fishery managers and policymakers. In so doing, it helps to bridge the gap between research and decision-making for hilsa and other fishery. This work also lays out some necessary foundations for a social resilience framework by identifying key issues underpinning social resilience and moving beyond a reduced focus on environmental management rules to the more holistic perspective of co-management. Finally, the findings help to understand the power dynamics that set the context for and exacerbate the persistent marginalization of resource users, especially in developing countries. Although this study focuses on Bangladesh's four coastal fishing villages, the results are potentially applicable across a broader perspective with a similar tropical context.

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LIST OF ORIGINAL PUBLICATIONS

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Article III. Mozumder, M. M. H., Pyhälä, A., Wahab, M., Sarkki, S., Schneider, P., & Islam, M. M. (2020). Governance and Power Dynamics in a Small-Scale Hilsa Shad (Tenualosa ilisha) Fishery: A Case Study from Bangladesh. *Sustainability*, *12*(14), 5738. https://doi.org/10.3390/su12145738

The publications are referred to in the text by their roman numerals. Reuse and reprints of the original articles are published with the permission of the publishers.

AUTHOR CONTRIBUTIONS

Article I:

The first author designed the research, developed the questionnaire, collected data, analyzed data, compiled the draft, and finally revised and checked the manuscript. A.P. supervised, read, and contributed substantial comments and edits to the manuscript. M.A.W. supervised, read, and edited the manuscript. P.S. supervised, read, and revised the manuscript. Additionally, S.S. and M.M.I. read and revised the manuscript.

Article II:

The first author designed the research, developed the questionnaire, collected data, analyzed data, compiled the draft, and finally revised and checked the manuscript. A.W. supervised, read, and edited the manuscript. P.S. supervised, read, and revised the manuscript. Also, S.S. and M.M.I. read and revised the manuscript.

Article III:

The author designed the research, developed the questionnaire, collected data, analyzed data, compiled the draft, and finally revised and checked the manuscript. A.P. helped to design the research, supervised, read, and contributed substantial comments and edits to the manuscript. M.A.W. supervised, read, and edited the manuscript. P.S. supervised, read, and revised the manuscript. Additionally, S.S. and M.M.I. read and revised the manuscript.

ABBREVIATIONS

AIGAs	Alternative Income Generating Activities
BOBLME	Bay of Bengal Large Marine Ecosystem
DPSIR	Drivers-Pressure-State-Impact-Responses
DENVI	Doctoral Program in Interdisciplinary Environmental Sciences
DoF	Department of Fisheries
EEA	European Environment Agency
ECOFISH-Bangladesh	Enhanced Coastal Fisheries in Bangladesh
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GoB	Government of Bangladesh
HFMAP	The Hilsa Fisheries Management Action Plan
IDS	Institute of Development Studies
LEK	Local Ecological Knowledge
MOFL	Ministry of Fisheries and Livestock
MCS	Monitoring Control Surveillance
NGOs	Non-Governmental Organizations
OECD	Organization of Economic Cooperation and Development
PCFA	The Protection and Conservation of Fish Act
SES	Social-Ecological Systems
SER	Social-Ecological Resilience
SSFs	Small-Scale Fisheries
UNO	Upazila Nirbahi Officer
UFO	Upazila Fishery Officer
USAID	United States Agency for International Development

1. INTRODUCTION

Scholars have been battling for years over the definitions of scale in fisheries. However, no clear or universal description of small-scale fisheries (SSFs) exists, nor is there a clear boundary between where the one sector ends, and the other begins (Smith & Basurto, 2019). Indeed, definitions differ based on which place is being referenced, and the expression "small-scale fisheries" can be interpreted in multiple ways by scholars and politicians. The interchangeable terms generally associated with SSF—such as "artisanal," "local," "coastal," "traditional," "small," "subsistence," "nonindustrial," "low-tech," and "poor"—are indicative of the many values and characteristics underpinning the definitions (Natale et al., 2015). For some scholars, the term "small-scale fishery" evokes a mental image of small, traditional fishing craft equipped with low-tech gear requiring labor-intensive fishing methods (Martin, 2005). SSFs are also essential in determining human health and nutrition, poverty alleviation, jobs, and the structure of seafood markets (Cohen et al., 2017).

SSFs have played a crucial role in meeting the basic needs of millions of people worldwide in both developed and developing countries (Allison & Ellis, 2001). Evolving accounts affirm that SSFs likely land nearly half the world's seafood, playing a critical role in food security and nutrition, especially for those living in poverty (Kawarazuka & Béné, 2010). In terms of employment, SSFs are by far the oceans' largest "employer"—higher than industrial fisheries, oil and gas, shipping, and tourism combined (World Bank, 2012). Nearly 90% of the world's 120 million full-time or part-time fishers are believed to derive their livelihood from the small-scale sector (Kolding et al., 2014). They are estimated to contribute 70% of the total world catch (inland fisheries included) and destined primarily for domestic human consumption (Mills et al., 2011). Furthermore, some 200–300 million people—many of whom are women—are projected to be employed in the value chain, mostly through informal arrangements. These figures, however, are most likely under-estimates because they are derived from official statistics from which SSFs are rarely well accounted (Mills et al., 2011). SSFs are, therefore, a significant but undervalued source of employment, food security, and income (Jentoft et al., 2011), mostly in the developing world and in rural areas (Bene, 2006).

SSFs are particularly critical to developing countries. According to recent estimates, 97% (~36 million) of the world's fishers are in developing countries, and 88% (~107 million) of the world's fishery and fish trade workers are employed in the small-scale sector in developing countries (FAO, 2018). Apart from contributing to global markets, SSFs are also essential for food security in

developing countries, where 62% of fishery production is locally consumed, and SSFs generate 55% of total fishery catches (FAO, 2018). Moreover, SSFs contribute to poverty alleviation and rural development through income generation and employment, as well as foreign exchange through international trade (Béné et al., 2010).

Despite these contributions, the sustainability of global fisheries is a growing concern, and the factors that enable and constrain the responsible management of SSFs remain poorly understood (Ünal & Franquesa, 2010). Meanwhile, many SSFs face growing challenges such as habitat degradation, climate change, a lack of financial sustainability, inadequate equipment and infrastructure, and a lack of access to markets (Cinner et al., 2012). Several other threats interplay with these, including competition with industrial fleets, water pollution, destruction of fish habitats, and an increasing human population and demand for land in coastal areas (Pomeroy & Andrew, 2011). Small-scale fishers usually live and work in hazardous environments, with poorly defined rights and representation in policy arenas: They remain poor and powerless. They are also in a constant struggle for survival (Islam, 2012).

Recent studies have found that globally, most of the small-scale fishing spaces are either heavily fished or overfished in degraded coastal and riparian ecosystems (FAO, 2018). With growing demand and new pressures such as climate change, lack of financial sustainability, inadequate equipment and infrastructure, and limited access to markets, it becomes ever more critical that SSFs are managed in sustainable and ethical ways (Allison et al., 2009). In meeting those challenges, there is a lack of adequate fishery management mechanisms in place. Overall, the sustainability and economic viability of SSFs are severely threatened and warrant improved governance (Salomon et al., 2019).

Governance is fundamental to fisheries; it determines how power and influence are exercised over their management (Chuenpagdee & Jentoft, 2018). Fisheries' governance is the sum of the legal, social, economic, and political arrangements used to manage fisheries. It has international, national, and local dimensions and includes legally binding rules as well as customary social provisions (Rohe et al., 2019). Today, it is widely accepted that the conventional approach (stock status and top-down regulatory measures) is unable to address the complex socio-economic characteristics, multiple livelihood needs, and multi-species nature of many SSFs (Purcell & Pomeroy, 2015). Leading scholars in the field agree that for SSFs to realize their potential as resources, it is vital to find appropriate ways to govern them (Armitage et al., 2009; Bene, 2006; Jentoft & Chuenpagdee, 2009).

1.1. Context of the Study

Hilsa fishery generates employment and income for millions of people in India, Bangladesh, and Myanmar, worth over USD 2 billion (BOBLME, 2012). The species has significant market demand, with a global average annual catch of about 0.72 million tons, of which approximately 50%–60% comes from Bangladesh, 20%–25% from Myanmar, 15%–20% from India, and 5%–10% from other countries (e.g., Iraq, Kuwait, Malaysia, Thailand, and Pakistan; (BOBLME, 2012). This study focuses on SSFs in Bangladesh, a low-lying, riverine country located in South Asia . The state has a coastal belt of 710 km along the northern littoral zone of the Bay of Bengal. Of the country's total population of 170 million, about 36 million people live in the coastal area, and their livelihood primarily depends on agriculture, fishery, forestry, nearshore transportation, and salt farming (Ahsan, 2013). Furthermore, the estuarine resources, including open water fisheries and SSFs, significantly contribute to the national economy and promote the socio-economic well-being of often impoverished coastal communities (Islam et al., 2016). Despite its significance, the fishing sector in Bangladesh faces several challenges. The marine fisheries are particularly vulnerable to collapse as the catch per fishing unit decreases due to declining fish and shrimp stocks (Islam et al., 2017).

Bangladesh is one of the world's leading fish-producing countries, with a total production of 4.134 million metric tons in 2016–2017, of which the hilsa (Tenualosa ilisha) catch makes up approximately 12% (DoF, 2018). Hilsa is an anadromous fish that spends part of its life in the marine ecosystem and part of the freshwater riverine system. It shows a distinct migration pattern from the Bay of Bengal to the rivers the Padma, Meghna, and its tributaries for breeding and nursing purposes (Islam et al., 2018). Hilsa is also found in the Indian Ocean and the Arabian Sea. Hilsa fishery in Bangladesh has a total annual value of USD 1.3 billion, accounting for more than 4.3% of the nation's total gross domestic product and employing approximately 2.5 million people directly and indirectly in the process (Islam et al., 2016) . Thus, hilsa has become the most valuable single-species fishery of Bangladesh.

Hilsa is also crucial to the Bangladeshi diet for its nutritional value, as it is rich in micronutrients and omega-3 fatty acids (Begum et al., 2016). The social and cultural significance of hilsa is also immense: Hilsa is honored as the national fish of Bangladesh and is considered essential in many religious, social, and festive events (Islam & Chuenpagdee, 2018).

Over the past few decades, the Government of Bangladesh (GoB) has passed several acts, ordinances, and rules to provide a framework for the utilization, development, management, and conservation of its fishery sectors and aquatic resources. In Bangladesh, fish—including hilsa—come from two primary sources:

inland and marine. The inland open water fisheries of Bangladesh operate under complex biological and institutional conditions. Two ministries—the Ministry of Land and the Ministry of Fisheries and Livestock (MOFL)—play significant roles in managing the country's fisheries. The Ministry of Land owns all inland open fishery resources except for privately owned waterbodies. The Ministry of Land is also responsible for the administration of leasing arrangements and regulation of access rights to these fisheries resources. The MOFL is responsible for the conservation, protection, and management of fisheries. The DoF, under the MOFL, is the central government organization mandated to develop this sector in Bangladesh. Under the Marine Fisheries Ordinance (1983), which sets the rules for marine fishery management and enforcement of regulations related to it, the DoF is responsible for the management, conservation, supervision, and development of marine fisheries, as well as issuing licenses for all marine fishing in Bangladeshi territorial waters. The DoF has taken several measures to conserve and manage hilsa fishery. As a migratory fish, both inland and marine fishery legislation is required for its management and conservation. Some laws that are not related directly to fisheries also have an impact on hilsa conservation.

In addition to the above, 12 other government departments are directly or indirectly involved in providing support for marine fisheries' development. The essential act regulating hilsa fishery is the Protection and Conservation of Fish Act (1950), as amended by the Protection and Conservation (Amendment) Ordinance (1982), while the main act regulating marine fisheries is the Marine Fisheries Ordinance (1983). Different initiatives, policies, plans, strategies, and projects have been implemented for hilsa fishery management by the GoB and non-governmental organizations (NGOs). The evolution of national hilsa governance is summarized in Table 1.

Table 1 Evolution of hilsa governance (revised from Islam et al., 2020)

Policy, plans, compliances, and projects	**Issues related to hilsa fishery governance**	**Year**
The Protection and Conservation of Fish Act (PCFA)	• Fishing nets with a mesh size of less than 4.5 cm are prohibited. • The manufacturing, import, marketing, storing, transportation, and owning and use of monofilament gill nets (Current Jal) are all prohibited.	1950
The Marine Fisheries Ordinance and Rules	• Two fishing zones for artisanal and industrial fishing, within and beyond a 40-m depth, are stipulated. • Fishing with gear that does not meet specified mesh size, and with any kind of explosives, poisons, or other harmful substances, is prohibited.	1983

The New Fisheries Management Policy	• Addresses the over-exploitation of fishery resources and inequality of fishing rights • Sets objectives for bringing the most significant benefits of all national fisheries to fishers instead of non-fisher elites • Adopts conservation measures to ensure that resources are sustained	1986
The National Fisheries Policy	• Aims to enhance fisheries' resources and production • Combats malnutrition by meeting the need for animal protein with fish • Aims to alleviate poverty through creating self-employment and enhancing the socio-economic conditions of fishers • Aims to achieve economic growth and earning foreign currency by exporting fish and fisheries products	1998
The Hilsa Fisheries Management Action Plan (HFMAP)	• Enforces compliance with conservation rules and regulations, as well as strategies related to hilsa fishery • Supports a sustainable hilsa fishery, protecting critical habitats, and builds the capacity of fisheries' actors • Offers alternative livelihoods for jatka fishers based on a compensation scheme • Raises mass awareness of the need for jatka and hilsa conservation	2003
Formation of hilsa sanctuaries	• The government declares four areas in the Meghna, Tetulia, and Andharmanik Rivers and some estuarine waters as hilsa sanctuaries. • Altogether, six hilsa sanctuaries are established by the government, following the HFMAP.	2005
The National Fisheries Strategy	• Promotes and supports collaboration, linkages, and partnerships for the benefit of marine fisheries • Promotes the participation of fishers and other stakeholders in the fisheries' value chain, local communities, the private sector, and NGOs in government programs through the Department of Fisheries	2006
Jatka conservation	• Provides food compensation to hilsa fisher households • Builds awareness of conservation, supporting alternative income-generating activities • Imposing regulations to prevent jatka and brood hilsa fishing during the ban periods	2008
Formation of the fifth hilsa sanctuary	• A 20-km stretch of the Padma River's lower basin from Narhira to Bhedarganj, Shariatpur district	2011
Formation of the sixth hilsa sanctuary	• At the confluence of the Meghna, Arial Kha, Kala Bador, and Kirton Khola Rivers	2018
Enhanced Coastal Fisheries in Bangladesh (ECOFISH-BD) project	• Fortifies science-based decision-making in hilsa fishery and its aquatic ecosystem • Steers adaptive co-management in the sanctuaries • Enhances the socio-ecological and economic resilience of fishing households and communities through improving policy, power, and incentives	2014–2019
The Protection and Conservation of Fish Act (PCFA)	• Fishing nets with a mesh size of less than 6.5 cm are prohibited.	2020

In recent decades, the availability of hilsa has drastically dwindled in aquatic systems across this region due to anthropogenic pressures—mainly intensive fishing, pollution, and river obstruction by dams and barrages (Sahoo et al., 2016). The decline in hilsa catch led the GoB to adopt different policies (Table 1) with conservation measures, including scientific fish stock assessments, no-take sanctuaries for juveniles during breeding seasons, and compensation for fishers adversely affected by the closures. Various law enforcement agencies enforce seasonal fishing ban periods, which are generally from November to January and March to April; these agencies also impose restrictions on the catch of juvenile hilsa (< 25 cm in length) from November to June in six existing fish sanctuaries (encompassing approximately 7,000 km^2) in the Meghna River and estuary (Figure 3). Furthermore, a comprehensive program has been executed for the protection of the renewable natural resources, ensuring the participation of all stakeholders, including local public representatives, the DoF, local administration, the Coast Guard, the Bangladesh Navy, fishers, and the mass people living in the hilsa-rich river system. Hilsa fishers are provided with grains to live on and provisions to start alternative income generating activities (AIGAs). As a result of these conservation measures, hilsa production had increased from 0.199 million metric tons in 2003–2004 to 0.517 million metric tons in 2017–2018 (DoF, 2018). Despite this management success of enhanced hilsa production, many dependent communities are still vulnerable to food insecurity and poverty, particularly during fishing ban seasons. Consequently, the hilsa restoration project's sustainability is at risk through over-exploitation, non-compliance with regulations, and conflicts over resource use (Rahman et al., 2020).

To avoid the collapse of hilsa fishery, and to sustain its ecological resilience, it is essential to enhance social resilience: the ability of individuals and communities to cope with disturbances and their means of adapting, transforming, and potentially becoming stronger in the face of socio-economic, political, and/or environmental challenge (Adger, 2000). A healthy community is a prerequisite for a healthy ecosystem (Liao et al., 2019; Morris, 1997). In this regard, the establishment of co-management regimes in the hilsa sanctuary areas could enhance the social and natural resilience of hilsa fisheries (Islam et al., 2020; Mozumder et al., 2018). Such management practices consist of a community-based process for common-pool resource management, which integrates institutions and actors at multiple scales of governance, from the state to the local. Moreover, co-management involves genuine power-sharing among the stakeholders (Trimble & Berkes, 2013). However, whether and how co-management can be done through power-sharing to mitigate the current sustainability challenges of hilsa fishery is to date unexplored. Furthermore, while the popular fascination with hilsa is widely celebrated, the power realities within which hilsa fishers

carry out their profession and daily livelihoods remain poorly understood or acknowledged both in policy circles as well as in the scientific literature.

1.2. Research Questions and Objectives

The primary goal of this dissertation is to provide state-of-the-art knowledge on the status of hilsa fisheries in Bangladesh, existing management approaches, their constraints and challenges, as well as the potential for enhancing social and ecological resilience through addressing current challenges, focusing particularly on prospects for co-management as a possible solution. To accomplish this primary goal, I pose the following research questions:

- What is the present state of hilsa fishery? What are the driving forces and pressures in hilsa fishery? What are the impacts of driving forces, pressures, and changes on local livelihood prospects? What are some possible responses to increase the sustainability of hilsa fishery? (Article I)
- What are the implications of hilsa over-exploitation on social resilience? Can co-management enhance social resilience, and if so, how? (Article II)
- How did the existing systems of governance in hilsa fishery develop and begin to operate? How is power exercised/distributed, and how does it discriminate among the stakeholders in hilsa value chains? What spaces (potential arenas for participation and action) and forms of power exist in hilsa fishery? How do they play out among different groups of stakeholders in each of these spaces? (Article III)

This dissertation comprises a summary section and three original research articles referring to three chapters in Roman numerals (I, II, and III), each corresponding to the research questions outlined above. In article I, I attempt to understand the social-ecological challenges of a SSF, namely hilsa (T. ilisha) fishery in Bangladesh (Mozumder et al., 2019). In article II, I aim to understand the dynamics of social resilience, including the implications of hilsa over-fishing on social resilience, and examine what is needed to enhance the social resilience of the coastal fishing communities in question (Mozumder et al., 2018). In article III, I use the power cube framework to analyze governance and power dynamics and what these mean for sustainably managing an SSF (Mozumder et al., 2020).

In this dissertation summary, I first present the theoretical frameworks used, followed by a description of the study methods. I then briefly summarize the three articles and their findings, followed by a short discussion of the results. I conclude with a reflection on the findings, the theoretical and practical contributions of the study, the limitations of this study, and suggestions for further research.

2. THEORETICAL FRAMEWORK

This dissertation draws on theories of socio-ecological systems (SESs), driver-pressure-state-impact-response (DPSIR), social-ecological resilience (SER, particularly social resilience), the power cube, and co-management as the guiding analytical frameworks. More specifically, I refer to SES and DPSIR in article I; SES, social resilience, and co-management in article II; and the power cube in article III. An outline of the theoretical frameworks is presented in Table 2 at the end of this section.

2.1. Social-Ecological Systems

The ecological legacies of a region shape human social and economic systems as a co-evolutionary process (Chapin et al., 2009). These processes occur in a variety of scales, from local to global. Therefore, scholars have recently suggested that the focus of sustainability science should be on linked SESs (Berkes & Folke, 1998). Nearly five decades have passed since the notion of an SES first was coined (Colding & Barthel, 2019). However, the concept was turned into a framework for the study of entwined human and natural systems within the last two decades (Berkes & Folke, 1998). Since that time, the SES concept has been used extensively in both the environmental and social sciences, along with in economics (Colding & Barthel, 2019). An SES is an ecological system that is intricately linked to and affected by one or more social networks (Anderies et al., 2004). In other words, in an SES, the role of humans is seen as an essential part of any conservation effort, due to positively enhancing interactions and feedback loops between the ecological and social subsystems (Cote & Nightingale, 2012). These subsystems include active links related to people's knowledge (often local or traditional) and management institutions, as well as the rules and norms that mediate how humans interact with the environment (Ostrom, 2009). Likewise, SESs are nested, multilevel systems that provide essential services to society, such as the supply of food, fiber, and energy (Berkes, 2017). Ecological endowments, in turn, help shape social and economic systems and occur in a variety of scales, from local to global (Béné et al., 2011). The loss of natural resources across various ecosystems, such as fisheries, forests, and water resources, is also an increasing concern worldwide (Mehlig et al., 2010).

An understanding of the processes that lead to improvements in, or deterioration of, natural resources are limited, because scientific disciplines use different concepts and languages to describe and explain complex SESs (Holling,

1973). A mounting body of literature supports the idea that SSFs, both inland and coastal, can be understood as integrated and critical SESs that incorporate both humans and nature (Adger, 2000; Béné et al., 2011; Ommer et al., 2012). SSFs are also important SESs in many developing countries: They provide essential ecosystem services and livelihood opportunities to communities that are often considered among the world's poorest and most vulnerable (Béné et al., 2011). Various research approaches have been developed and applied in different studies, in which the interaction between the social system and the ecological system has been explicitly considered (Ommer et al., 2012). Concurrently, frameworks have been developed to establish a common language to structure research into SESs, and to provide guidance toward a more sustainable SES development (Pahl-Wostl, 2009). There are three major analytical frameworks that scholars commonly adopt and are inspired by when studying interlinked SESs (Colding, & Barthel, 2019). First, the original SES framework developed by Carl Folke and Fikret Berkes has been primarily used to address what confers institutional resilience and how can institutional resilience be combined with ecological resilience for mutual benefit (Berkes & Folke, 1998). Second, the robustness framework developed a model for examining the robustness of SESs with the purpose of highlighting key interactions within SESs that were especially important with regard to robustness, signifying designed resilience used in engineering when disturbances and shocks are known and the system is being built and designed to withstand these known shocks (Anderies et al., 2004). Third, multitier frameworks enable researchers to organize second-tier variables in a nested fashion and improve understanding of how these variables may affect and be affected by the larger socioeconomic, political, and ecological settings in which they are embedded (Ostrom, 2009). Such frameworks help sustainability science scholars identify variables that either sustain or collapse the resource management systems under study (Colding & Barthel, 2019).

The SES framework provides an analytical perspective to better understand the multiple interactions among elements of SESs to influence the opportunities for conservation strategies (Schlüter et al., 2014). Analyzing contemporary SESs requires coherent models and methodologies that recognize the complex and interconnected nature of society and the environment and question traditional modes of governance (Holling, 2009). The problems in an SES can be addressed at a social, economic, or ecological level, as well as at a regulatory level through governance and management structures (Olsson et al., 2006). This endeavor requires a societal response from the SES's interested stakeholders, demonstrating the society's capacity to respond to deteriorating situations and to solve problems or mitigate damage (Crépin et al., 2017). This is also true for hilsa fishery, for which I have employed this theoretical framework (in article I). In article II, I elaborate on how fisheries are complex SESs, and why it is

essential to incorporate fishers' traditional knowledge, experiences, observations, and opinions into fishery management policies and the implementation of those policies.

2.2. Driver-Pressure-State-Impact-Response

The DPSIR framework is one framework that is related to natural resource management. It is important for generating information that promotes the development of appropriate policies and regulation for effective management and utilization of different aspects of ecosystems (Dzoga et al., 2020). The DPSIR framework also provides a connection between the causes of environmental problems and the resulting pressures, related effects, and responses needed to resolve and manage specific environmental issues and challenges (Carr et al., 2007).

The DPSIR framework was originally developed to provide a better understanding of indicators and appropriate responses to human activities' impacts on the environment, to support decision-making, by capturing key relationships between society and nature (McKenzie, 2004). The main objective of the DPSIR framework is to promote sustainable management of natural resources by providing a common forum and language for environmental managers, scientists of different disciplines, and other actors (Gari et al., 2015). The Organization of Economic Cooperation and Development (OECD) and the European Environment Agency (EEA) have developed the DPSIR framework as a tool for SES analysis (Lewison et al., 2016). According to its terminology, social and economic developments (driving forces, D) exert pressure (P) on the environment (the specific human activities that result from driving forces which impact the environment), consequently, the state (S) or condition of the environment changes. This leads to impacts (I) on ecosystems, human health, and society (the ways in which changes in state influence human well-being), which may elicit a societal response (R) that feeds back on driving forces, states, or impacts, via various mitigative, adaptative, or remedial actions (Figure 1; Smeets & Weterings, 1999). Thus, DPSIR is described as a causal framework used to illustrate the interactions between society and the environment (Binimelis et al., 2009).

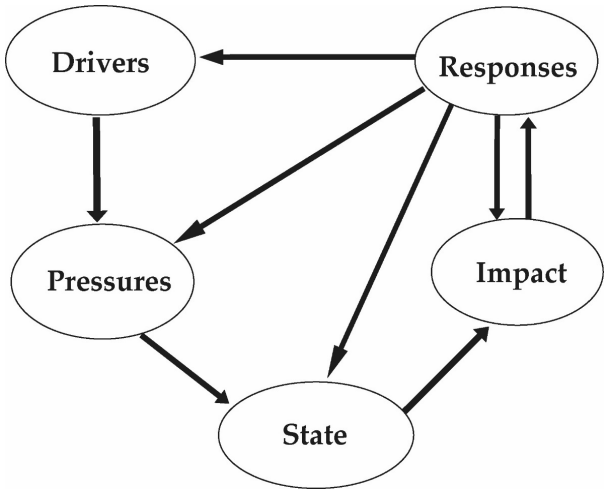

Figure 1 The general driver-pressure-state-impact-response framework (Smeets & Weterings, 1999)

The DPSIR framework has been applied worldwide across various levels and settings, from global to national scales (Carr et al., 2007). After its adoption by the EEA in 1995, DPSIR became popular in studies involving the management of nutrient fluxes in marine environments (Scheren et al., 2004), integrated coastal management (Bowen & Riley, 2003), in assessing linkages in human pressure with coastal and marine ecosystems (Patrício et al., 2016), and development in catchment areas and offshore wind power generation (Elliott, 2002). The DPSIR framework has also been used for parallel assessments comprising environmental and socio-economic perspectives and impacts (Agyemang et al., 2007).

Notwithstanding the value and potential for environmental assessment and management, the DPSIR framework has been criticized for possessing several weaknesses (Carr et al., 2007; Niemeijer & De Groot, 2008; Rekolainen et al., 2003). Criticism of the framework mainly refers to its implicit hierarchical structure, which causes a hierarchy of elements and, therefore, also of actors (Carr et al., 2007). Individuals and groups who are affected by social and environmental changes have only the potential to address impacts and the conventional use of the DPSIR approach implies the existence of neutral knowledge of environmental interrelationships. Thus, DPSIR excludes normative perspectives and concerns (Svarstad et al., 2008). Rather than addressing complex inter-relationships, DPSIR has also been criticized for focusing on causal chain, one-to-one relationships (Niemeijer & De Groot, 2008). Finally, DPSIR is not a model but rather a means of categorizing and disseminating information related to environmental challenges (Carr et al., 2007). In this dissertation (article I), I used the DPSIR framework to analyze the state and challenges of hilsa fishery in the Gangetic River systems (Padma & Meghna Rivers).

2.3. Social-Ecological Resilience

SER is the capacity to adapt or transform in the face of change in the SES, particularly to unexpected turns, in ways that support human well-being (Cumming et al., 2015). At the core of the SER approach to managing human–nature relations is the concept of resilience (Mehlig et al., 2010). Resilience theory, with its origin in ecological integrity assessment (Holling, 1973), has evolved within a few social-science-related fields, including economics (Perrings, 2007), anthropology (Vayda & McCay, 1975), psychology (Masten & Obradovic, 2008), political ecology (Peterson, 2000), and development studies (Brown, 2014). Thus, in recent years, resilience has been adopted in interdisciplinary discourse concerning coupled human–environment systems, particularly regarding the natural environment and communities dependent thereon, where human and environmental nexuses are prevalent (Adger, 2000).

Research on SER has, in recent years, been growing progressively. Nevertheless, the link between ecological and social resilience is not entirely clear (Finkbeiner et al., 2017). While it is expected that a resilient ecosystem has the potential to support resilient communities and vice versa (Islam et al., 2018), this interaction is not straightforward. For instance, resilient ecosystems' social outcomes are often mediated by several factors, such as the communities' resources, rights, and access to the environment (Finkbeiner, 2015). Ecosystem outcomes are also dependent on social factors such as tenure within management regimes, markets, and technological factors (Darling et al., 2019). Examining this intricate link between social and ecological resilience requires in-depth consideration of social institutions (i.e., the formal and informal rules governing human behavior; (Schlager & Ostrom, 1992), as well as the roles of power and politics in enabling individuals, households, and communities to benefit from ecological resilience (Leach et al., 1999).

Ecological resilience is a well-established concept: the capability of an ecosystem to tolerate and respond to biotic, abiotic, and anthropogenic disturbances through adaptive responses (Bradley & Grainger, 2004). In contrast, social resilience is a less-common term. It is the ability of society (individuals, groups, communities) to cope with change, including shocks to their social infrastructure; however, it has also been used to explain disaster management (Maguire & Hagan, 2007), preventing degradation resulting from the over-exploitation of land in response to drought and other constraints (Bradley & Grainger, 2004), uncertainties in small-scale fishing (Anna & Fauzi, 2010), climate variability (Marshall, 2010), commercial fishers' reactions to management (Sutton & Tobin, 2012), and resource dependencies (Marshall et al., 2007).

Despite the similarities in definition, there are inherent challenges in bringing together the "social" and the "ecological" in these notions of resilience, and

there is still a distinct knowledge gap concerning the social aspects of resilience (Davidson, 2010). One of the fundamental differences between social resilience and ecological resilience is that in social resilience, the adaptive capacity in question relates to the ability of humans to intentionally influence their circumstances (Nelson et al., 2007). Thus, understanding social resilience calls for explicit attention to power relations and the unequal distribution of agency (Berkes & Ross, 2013). Furthermore, whether an individual or community can adapt to change (i.e., be resilient) depends on the degree of perceived risk involved in different types of change and uncertainty (Brown & Westaway, 2011). Overall, processes of politics, power, and agency need to be understood to address issues of social justice, equity, and human well-being (Davidson et al., 2016). In addition, knowledge of the properties of social resilience can help managers and resource users design policies that minimize adverse impacts on people and maximize the sustainability of the goods and services derived from the ecosystem (Maclean et al., 2014). Understanding how social resilience can be conceptualized and operationalized is thus an essential focus in the present research, primarily as it relates to the sustainability of SESs and resource-dependent communities (Maclean et al., 2014).

2.4. Power Cube

A myriad of tools and methods can be used to analyze power relations among stakeholders in natural resource management (Bjuremalm, 2006; Whaley & Weatherhead, 2015). However, the power cube framework (Figure 2; Institute of Development Studies [IDS], 2009) is well recognized and has been used by scholars in several related studies (Jacobi & Llanque, 2018; Njaya et al., 2012). I chose to use this approach as a complementary analytical framework to examine the power relations among local hilsa fishery stakeholders. The following section is modified from the IDS for the analysis of spaces, forms, and levels of power (IDS, 2009).

Power cube is a conceptual framework that can be used to understand and analyze how power works in processes of governance and citizen participation in organizations and social relationships (IDS, 2009). It uses a multi-faceted approach to explore the visible, hidden, and invisible dimensions of power by mapping the various spaces and levels where stakeholders experience and exercise these forms of power. Though visually presented as a cube, it is vital to think of each side of the cube as a dimension or set of relationships, not as a fixed or static set of categories (Figure 2; IDS, 2009).

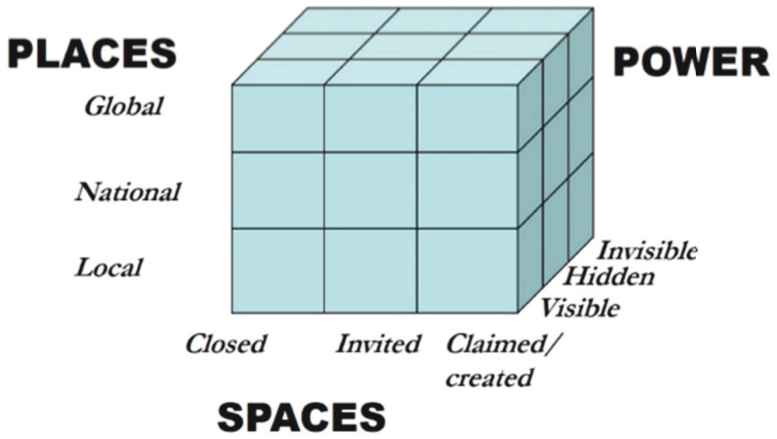

Figure 2 The power cube framework (IDS, 2009)

In the power cube framework, places refer to the levels where participatory action takes place. These can be at the local (household, village, or district) level, the national level, which involves national networks or national assemblies, or the international level, which includes regional bodies or systems. Scholars contend that participatory practices must begin locally because, in the arenas of everyday life, people can resist the power and construct their voice. In this dissertation, I focus on an adapted version of the power cube framework, adopting two of the three dimensions of the framework for analysis, namely local level (household, fishing boat crew, village, Upazila referred to as sub-district) and national level (district).

The spaces dimension, in turn, refers to the potential arenas for participation and action, including what we call closed, invited, and claimed spaces. Closed spaces refer to those decision-making spaces where only the most elite stakeholders (politicians, experts, managers, etc.), in closed-door meetings, can participate in decision-making. Invited spaces are instances where efforts are made to widen participation, move from closed spaces to more "open" ones, and create new spaces. Into these new spaces, a wider variety of stakeholders (users, citizens, or beneficiaries) may be invited by various authorities (governments, supranational agencies, or non-governmental organizations) to participate. Claimed/created spaces, in turn, are the spaces encompassed by less powerful stakeholders from or against the power holders or created more autonomously on a grass-roots level.

Finally, the forms dimension of the cube refers to how power manifests, including visible, hidden, and invisible ways. Visible power includes the definable aspects of political power: formal rules, structures, authorities, institutions, and decision-making procedures. Visible power is also understood by the following

axiom: A has power over B to the extent that it can get B to do something that B would not otherwise do. In contrast, hidden power involves certain influential people and institutions maintaining their influence by controlling who gets to sit at the decision-making table and what gets put on the discussion and decision list. These dynamics may operate simultaneously at many levels to exclude and devalue the concerns and representation of less powerful groups. Invisible power refers to social and cultural norms, perceptions, and beliefs that condition or influence people's individual or collective views.

2.5. Co-management

Co-management is a popular and evolving concept in natural resource management, with many benefits ascribed to it (Berkes, 2009). When used appropriately, i.e., involving all resource users and stakeholders in natural resource management, it offers both normative and objective interests. In an objective sense, co-management can lead to more effective resource conservation and less costly management, for example, when used to manage a fishery (Jentoft et al., 1998). Hence, co-management is also widely promoted as a preferred approach for managing complex SESs associated with SSFs (Linke & Bruckmeier, 2015). It ideally combines the best of top-down and bottom-up approaches, linking resource users, government agencies, and other stakeholders through vertical and horizontal connections, and providing mechanisms for collaboration and adaptive creativity (Quimby & Levine, 2018).

Co-management scholars agree that the most critical aspect is the genuine sharing of authority and responsibility for the management of a resource between local resource users and the government (Pomeroy & Berkes, 1997). Co-management can also be a way of refining the social resilience of local communities, enabling them to have more power and control over decisions regarding how the natural resources they depend on are to be used (Marshall et al., 2007). The co-management approach also considers issues of scale, such as administrative and geographic boundaries, institutions, rule systems (formal and informal), shared decision-making, and collective learning among actors that can help to develop more robust SESs (Anderies et al., 2013).

There are also disadvantages associated with co-management. Co--management projects are far from always leading to the intended positive outcomes (Evans et al., 2011). They can also be particularly time-consuming, expensive, and destructive of social capital (Conley & Moote, 2003). They can generate illegitimate conflicts and lead to compromises based on the lowest common denominator (Kenney, 1999). Some studies of co-management suggest that institutions may be limited in their ability to adapt to socioeconomic and

socio-ecological change (Davis & Ruddle, 2012). For example, co-management systems often shift the burden of responsibility onto resource users' local institutions to overcome dilemmas (Davis & Ruddle, 2012). This shift in responsibility often neglects a nuanced understanding of the realities of many resource-dependent communities, including the disparity in users' access to resources and the social inequality and poverty they face (Béné & Friend, 2011; Davis & Ruddle, 2012). In addition, initiating a co-management approach requires a substantial investment in the form of time and human resources in the short term (Kofinas, 2009). Poor leadership and a lack of community organization may reduce the effectiveness and sustainability of co-management (Nielsen et al., 2004).

In this dissertation, I emphasize co-management of fisheries, where co-management has been promoted as a way of improving the effectiveness and efficiency for at least the past two decades, recognizing that the inclusion of resource users in management should promote strengthened understanding, ownership, and commitment (Levine, 2016). While management (implementation of legislation) and governance (formulation of legislations and decisions) are different, governance within fisheries has often been equated with co-management (Schmitt, 2011). Although scholars define fisheries' co-management differently, the concept emerged as a way of increasing the stake of local actors in decision-making for fisheries management by power-sharing, implying a partnership among fisheries' users, related business enterprises, NGOs (including donor agencies), and the government (Jentoft, 1989; Pomeroy & Berkes, 1997; Sen & Raakjaer Nielsen, 1996).

There are several fundamental principles of fishery co-management: participation, representation, equity, empowerment, and power-sharing (Quimby & Levine, 2018). Participation is an essential component of knowledge sharing, negotiating identities, needs, and values of different groups and individuals (Berkes, 2009). Participation can also provide social benefits to communities through a more effective incorporation of local needs and priorities (Mubita et al., 2017). Participation has been the explicit focus of many studies of SSF co-management around the world (Alam & Begum, 2005; Aldon et al., 2011; Chrysafi, 2019; Hanna, 1995).

Four questions need to be considered when analyzing representation in fisheries co-management (Jentoft et al., 2003): (i) Who can legitimately claim to be recognized as a user or stakeholder?; (ii) In what capacity should users and stakeholders be represented?; (iii) How much involvement should there be?, and; (iv) How should representation be carried out? This dissertation attempts to find answers to those questions regarding co-management arrangements in Bangladeshi hilsa fishery.

Equity, in turn, has been a central goal of community-based management and conservation efforts for decades, and achieving social equity and justice in co-management settings is increasingly seen as key to long-term sustainability (Jentoft, 2013). In the SSF context, equity means who gets what, relative to others. Based on rules or norms, it can improve livelihoods, decrease poverty, and reduce vulnerability among fishers (Kittinger, 2013).

Empowerment is both a condition and a goal of fisheries co-management (Wilson, 2003). Empowerment involves bringing previously excluded, marginalized, and sometimes alienated user groups and stakeholders into the management decision-making process, by reshuffling power and responsibility among those who form the fishery management chain (Jentoft, 2005). For fishery co-management to become sustainable, empowerment must occur at both a collective and an individual level (Pomeroy et al., 2001; Viner et al., 2006).

Finally, a continuous state of power negotiation and power sharing is the backbone of successful co-management arrangements (Jentoft, 2007). It is often described as a shift away from top-down, state-driven management to a participatory, multi-scaled approach that partners government organizations, local communities, resource users, and often regional or international NGOs (Turnhout et al., 2010). In fishery co-management, power is considered an opportunity to participate in, and influence, decision making in the management of fisheries resources (Ho et al., 2015). Power can be a constructive force, but it can also be disruptive and corruptive and serve special interests (Jentoft, 2007). Thus, power is relative; it characterizes relationships between individuals or groups (Carlsson & Berkes, 2005). Furthermore, equal sharing of power occurs when the resource users, including all actors in the value chain, have the same rights as the government in making decisions over resource management (Sen & Nielsen, 1996).

To avoid undercutting community authority, power relationships should be understood and examined as embedded within an SES, such as SSFs in this case (Quimby & Levine, 2018; Rivera & Newkirk, 1997). There is little consensus in the literature as to how power dynamics affect linkages between desired outcomes and different forms of governance in SSFs (Crona & Bodin, 2010). Discussions about power in co-management often center around the formal institutions and overt processes where leadership and authority are negotiated, mainly formal power-sharing arrangements between the state and the community. However, implicit forms of power, and the way that these shape co-management arrangements and outcomes, remain under-recognized and under-analyzed (Quimby & Levine, 2018), a gap that this thesis aims to fill.

2.6. Integration of the Theories

While the substance of this dissertation is primary analytical, providing relevant and up-to-date data regarding the situation in Bangladesh's coastal hilsa fishery, there is also an ideological, teleological element to this research, which can be seen in the interplay of the five primary theoretical frameworks applied here. I hope and anticipate that, beyond providing professional reading for academics and officials in relevant fields, this work may ultimately serve as a means to improve both the lives of small-scale fishers and the ecological resilience of the environment on which their livelihood depends. For this to happen, the holistic nature of the human and biological environment must first be recognized (the SES framework). Then, the ways in which the elements within this environment affect each other must be extensively examined and modeled (the DPSIR framework). Next, a sort of target direction must be set, according to which any overall claims of "improvement" or "degradation" can be evaluated in context (the SER framework). In the penultimate step, the complex, yet subtle power dynamics involved on the strictly human side of the issue must be examined in some detail (the power cube framework). Finally, a tool by which these issues of power can be influenced to better conform to our teleology must be proposed (the co-management framework). Thus, these frameworks come together in the hope of perhaps making Bangladesh's coastal hilsa fishery of Bangladesh a better place, in a way that can also serve as a model for improving other parts of the world.

Table 2 Outline of the theoretical frameworks

Theoretical framework	Purposes
Social-ecological system	To conceptualize the social, ecological, and governance components of hilsa fishery, their interactions, and the outcomes of these interactions
Driver-pressure-state-impact-response	To enable the identification and establishment of causal links between anthropogenic activities affecting hilsa fishery and the environment, allowing for the concrete development of responses for sustainable fishery management
Social-ecological resilience	The capacity to adapt or transform in the face of change in social-ecological systems, in particular to unexpected turns, in ways that continue to support human and ecological well-being
Power cube	Used to comprehend and analyze how power works in processes of governance and citizen participation, both in organizations and across social relationships
Co-management	Provides a grounded approach to address the process of knowledge generation, organization, and problem-solving for the further development of management planning for hilsa fishery

3. METHODOLOGY

In this dissertation, I use a qualitative case study approach, which facilitates the exploration of a phenomenon within its context using a variety of data sources. This approach ensures that the issue is not examined through a single lens, but rather a variety of lenses, allowing for multiple facets of the phenomenon to be revealed and understood (Baxter & Jack, 2008). In addition, the case study approach is particularly suitable for holistically examining an event in its interactions with its context, for answering questions of "How?" and "Why?" (Yin, 2013). Beyond that, I chose to follow a qualitative methodology because it enabled me to consider my interviewees' areas of expertise more flexibly. Below I present in more detail my methodological approach. A summary of the research methods applied in this dissertation is presented in Table 3.

3.1. Ethical Considerations

This research adheres to the ethical codes of the Society of Ethnobiology.[1] Working with local fishing communities also involves sensitivity to the specific values, rules, duties, and virtues of relevance to both human and ecosystem well-being, providing a critical normative analysis of the moral issues at stake in that sector of human activities (Macer et al., 2003). Before each interview, I informed respondents about the study and given assurance about ethical principles, including rights to anonymity and confidentiality. Furthermore, prior to each interview, I shared my intention for data collection and obtained verbal informed consent. Prior permission was obtained for all recordings of interviews and photographic documentation. When interviewees so preferred, I wrote notes rather than recording the interview. Participation in the research was entirely voluntary, and all participants were informed of their right to withdraw from the study at any stage. Interviews were carried out in the local dialects and language (Bengali).

1 https://ethnobiology.org/about-society-ethnobiology/ethics

3.2. Study Areas

To obtain the empirical data for this dissertation, I conducted fieldwork in four hilsa fishing communities in Bangladesh (Figure 3), in the villages of Rahmatpur and Sudirpur (Kalapara Upazila of the Patuakhali district, study area 1) and Uttar Bagula and Dakxin Bagula (Haimchar Upazila of the Chandpur district, study area 2). Choosing different study areas provided a diverse view of coastal SSFs, which vary considerably, depending on circumstances and places (Jentoft et al., 2011) along the coast of Bangladesh. Furthermore, data from just one community would have been too limited to provide reliable answers for my research questions.

The chosen study areas are situated in two important sanctuary sites (protected areas, considered to be an essential measure for the conservation and management of hilsa fishery resources) within hilsa fishery declared by the GoB in 2005. The selected communities are directly dependent on fishing within the sanctuary areas for their livelihoods from fishery-related activities, including fish drying, fish trading, net mending, boat making, and boat repair.

With a total population of approximately 12,000 people, study area 1 is situated in the southwestern part of Bangladesh, along the Andharmanik River, Kalapara Upazila (sub-district), Patuakhali district (Figure 3). The Andharmanik River is a well-known hilsa breeding and nursery ground. Hence, it was declared the fourth hilsa sanctuary by the GoB and has set closure periods for catching juveniles (jatka; November–January) and breeding female hilsa (22 days within October–November based on the lunar cycle; (Islam et al., 2018). Study area 2, where approximately 8,000 people live, is located along the lower Meghna River, Haimchar Upazila, Chandpur district, in the southeastern part of Bangladesh (Figure 3).

The Meghna River is considered one of the most significant breeding zones for hilsa, and the GoB declared 100 km of the lower Meghna River as a hilsa sanctuary in 2005 to retain hilsa juveniles and broodstock.

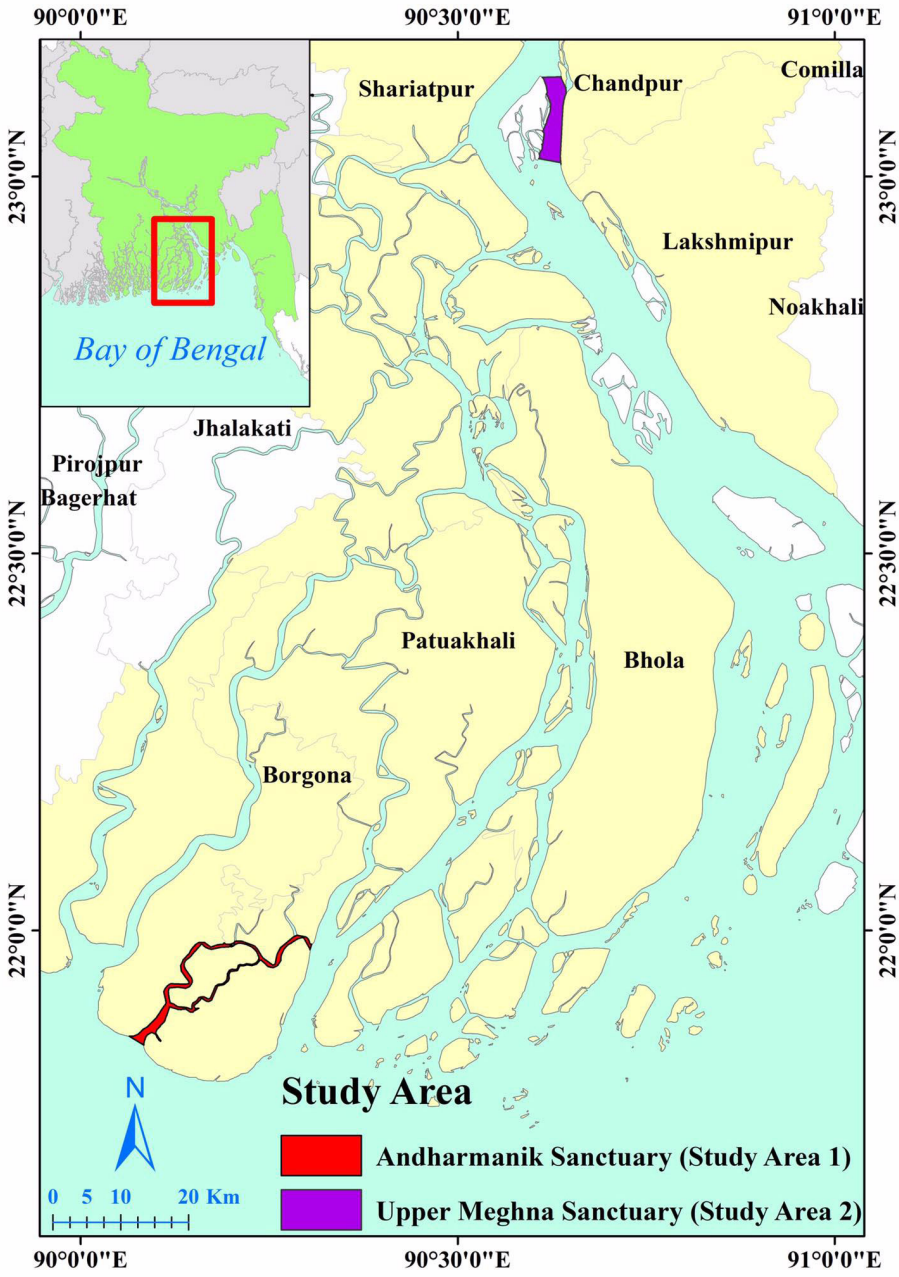

Figure 3 Study areas in Bangladesh and a map of hilsa sanctuaries; adapted from (Islam et al., 2020) with permission

3.3. Data Collection

A combination of primary and secondary data sources was used in this study. Data were collected in two stages: in study area 1, data were collected from December 2016 to February 2017; and in study area 2, data were collected from November 2018 to January 2019. For empirical data, I used qualitative methods, namely in-depth individual interviews and focus group discussions (FGDs). Individual interviews provided an understanding of details regarding each interviewee's perspectives on their lives, experiences, and situations, expressed in their own words (Lambert & Loiselle, 2008). Hence, I collected a significant part of the empirical data from in-depth interviews, each of which lasted approximately one hour on average. However, FGDs helped with insights into matters of local consensus and diversity of viewpoints (Etikan, 2016; MacDougall & Fudge, 2001). I also used FGDs to obtain participants' knowledge, perspectives, and attitudes about issues and to seek explanations for behaviors in a way that would have been less accessible in responses to direct questions in one-to-one interviews (Cameron, 2005).

The interviewees come from different occupational backgrounds among hilsa fishery stakeholders, namely hilsa fishers (men and women), fish traders, boat owners, money lenders, local government representatives, and local government administrative personnel. In conjunction with hilsa fishery stakeholders, I interviewed academics, local NGO representatives, and environmental specialists. The purpose of the interviews with different respondents was purely qualitative, specifically to explore the range of opinions and the different representations of the issues at hand. The objective was to maximize the opportunities to understand the different positions and views taken by the members of the communities (Bauer & Gaskell, 2011).

The interviews were semi-structured but allowed for open-ended conversation. I modified interview questions where necessary, considering the respondents' understanding of the questions. The questions were adapted based on the role and representation of the interviewee. A list of topics and possible questions for each interviewee focused on the overarching themes based on the research questions of the study (interview questions are attached in the respective articles' supplementary files).

In the FGDs, I developed a list of similar questions beforehand, but new questions could emerge during the discussions. During the FGDs, I played the role of moderator and, with permission of all participants, my research assistant recorded the FGDs. Each FGD lasted approximately one hour. Priority was given to interviewing inside the living areas or workplaces of the interviewees. I avoided busy working hours, and I conducted interviews while fishers were netting or repairing their boats or nets. I also conducted interviews in usual gathering

places, such as at a tea stall. I took extra caution when interviewing fisherwomen, considering the general norms of propriety for each society.

The interview sample size was determined based on the requirement of information and guided by the principle of data saturation (Francis et al., 2010; Mason, 2010). I used purposive and snowball sampling strategies to select the interview respondents (Teddlie & yu, 2007). I employed a snowballing sampling method to identify potential fishers to interview because of the diverse group of people engaged in hilsa fisheries (Streeton et al., 2004). I utilized a purposive sampling approach to interview the more knowledgeable fishers (Tongco, 2007). Sampling was mainly conducted in places where the fishers gather (fish landing sites, riverbanks for harboring boats, flood protection embankments, markets for selling fish, and tea stalls). These selected places are also where both women and men gather, including those who usually do not travel outside of the communities for various reasons such as religious rules, disability, or illness.

For the present study, I collected secondary data regarding aspects of the situations and events that were not sufficiently addressed in the primary data. Secondary data sources included articles from daily newspapers, study reports issued by NGOs and local universities working with SSFs (mainly for hilsa fishery) in the coastal areas of Bangladesh, and associated legislation issued by the GoB. Moreover, these data were embedded in a scientific literature review related to research objectives. In this manner, the reviewed literature helped to better design and contextualize the research questions, interviews, and sampling strategy (Bowen, 2009), and proved to be useful in validating many of my findings (Yin, 2013), on which I further elaborate in the discussion part of the thesis.

3.4. Data Analysis

The qualitative data from the in-depth interviews and FGDs were transcribed, translated from Bengali to English, and analyzed using content analysis (article II) and thematic analysis (articles I and III) for related themes (Braun & Clarke, 2006; Vaismoradi et al., 2016). The reason for choosing content and thematic analysis is that both approaches allow for a qualitative data analysis (Vaismoradi et al., 2016). This process helps interpret and code textual material (e.g., documents, books, oral communication, interviews, and graphics) to elicit meaningful information covering different themes. Specifically, in article I, I used the inductive approach of content analysis to answer the question of what the fundamental local problems were that co-management could solve, and what the underlying issues were that co-management approaches should consider (Elo & Kyngäs, 2008). On the other hand, thematic analysis is particularly useful for drawing classifications and contemporary themes (patterns) that relate to the

data (Braun et al., 2019). This illustrates the data in detail and deals with diverse subjects via interpretations. I related themes to specific research questions to guide further data analysis. I also used direct quotations to support and clarify the perceptions of the respondents. Initial analyses of the data were made jointly with the respondents in the field to eliminate personal biases in interpretation. For this dissertation, I used an entirely manual procedure to analyze the qualitative data, i.e., I did not utilize analytical software.

3.5. Positionality, Validity, Consistency, and Limitations

The concept of positionality is based on the notion that the researcher's characteristics vis-á-vis the respondents can influence the data produced (Berger, 2015). Positionality is a critical factor in framing social and professional relationships in the field; it sets the tone of the research, affecting its course and outcomes (Chacko, 2004). Accessing local informants, developing relationships of trust with them, and acquiring quality data that reflect "truths" are prime considerations for field researchers (Shenton & Hayter, 2004). Government officials, local elites, the NGOs' staff, and other actors with power are often the ones who assist in making local contacts (Fielding et al., 1994).

Conducting interviews comes with severe restrictions and challenges in rural Bangladesh. The notion of an interview as a simple encounter between an interviewer and individual respondents is highly unlikely in a rural Bangladeshi community (Islam, 2012). The limitations that I faced together with my research assistants while conducting the interviews were many. The interviews quite often took place in the presence of other men or women who interfered in the conversation, thus creating a group response. In the reverse cases, a respondent might show little interest or reluctance to give enough time for the interview, or even challenge it. Many fishers in the study areas are not interested in providing qualitative interviews because these take up valuable time from their working day. As we were outsiders, some fishers did not want to share their perceptions in interviews. The fishers frequently inflated their livelihood constraints with the hope that we would provide aid. The strategy employed to overcome the above challenges was that we stayed in the fishing village and visited them regularly to build trust. We also offered tea and light snacks to the interviewees as a complementary gesture.

Given these considerations, I already had valuable knowledge and experience working with fishing communities in Bangladesh. I established informal relationships with the village leaders and many fishers, and these friendly relations proved useful during the entire duration of my data collection. I was trusted with personal and sensitive information. I never used the "standard

official language"; rather, I used local dialects in both study areas to retain information or ideas intact during translation, to keep the discussion lively, and to maintain a friendly and respectful atmosphere.

Validity and consistency are the two important factors while designing qualitative research and judging the quality of research (Golafshani, 2003). I took several steps to ensure the validity of the present study. First, I chose the study areas carefully to guarantee that my research objective addressed the specific problems of the selected communities (Stenbacka, 2001). I employed semi-structured interview guidelines, which allowed for open-ended discussions, provided for much more relaxed and open conversations, and let all respondents speak freely according to their knowledge and perceptions. I was also cautious in detecting and stopping the interview or FGD at the saturation point, where no new information was available. During the interview process and FGDs, the discussion was tape-recorded, and notes were taken on paper for key points raised. With the aim of clarification, communication, and cross-checking, I shared preliminary results with the interviewees at the end of the FGDs. The findings of this study and draft articles were presented in the Doctoral Program in Interdisciplinary Environmental Sciences (DENVI) at the University of Helsinki seminars and at other symposia and conferences.

Table 3 Outline of research methods

Article	Method of data collection		Sampling approach	Methods of data analysis	Study area
	Number of individual interviews	Number of focus group discussion			
I	130[2]	8	Snowballing; purposive	Thematic	1 & 2
II	60[3]	2	Snowballing	Content	1
III	128[4]	8	Snowballing; purposive	Thematic	1 & 2

2 The 120 interviews were with hilsa fishery stakeholders, and in each of the four villages, interviews were undertaken with 20 individual hilsa fishers—mostly men (n = 15), but also a few women (n = 5). An additional 10 interviews were conducted with other stakeholders, including fish traders (n = 2), boat owners (n = 2), money lenders (n = 2), local government representatives (n = 2), and local governments administrative personnel (n = 2). Along with hilsa fishery stakeholders, academics were interviewed (n = 4), local NGO (representatives (n = 2), environmental specialists (n = 2), and aquaculture specialists (n = 2).

3 There were 30 interviews in each village, 20 with hilsa fishers (men, n = 15; and women, n = 5). An additional 10 interviews were conducted with other stakeholders, including fish traders (n = 1), boat owners (n = 1), money lenders (n = 2), local NGO representatives (n = 2), local government representatives (n = 2), and local governments administrative personnel (n = 2).

4 The 120 interviews were with hilsa fishery stakeholders, and in each of the four villages, interviews were undertaken with 20 individual hilsa fishers—mainly men (n = 15 per village), but also some women (n = 5 per village). An additional 10 interviews were conducted with other stakeholders, including fish traders (n = 2 per village), boat owners (n = 2 per village), money lenders (n = 2 per village), local government representatives (n = 2 per village), and local governments administrative personnel (n = 2 per village). In conjunction with hilsa fishery stakeholders, academics (n = 4), local NGO representatives (n = 2), and environmental specialists (n = 2) were interviewed.

4. RESULTS AND DISCUSSION

In this part of the dissertation, the findings of the three research articles and a discussion of the main findings are summarized. The findings are described in more detail in the respective articles. Each article used different sets of theoretical backgrounds, methodologies, and research questions, thus generating results of a distinct nature, but each contributes significantly to the overall findings of this dissertation.

4.1. Understanding the Social-Ecological Challenges of a Small-Scale Fishery (Article I)

Article I (Mozumder et al., 2019) analyzes the state and challenges of hilsa fishery in the Gangetic River system (the Padma and Meghna Rivers) by using two frameworks: SES and DPSIR. The results suggest that the main driving forces for a decreased catch by fishers are the use of illegal fishing gear, overpopulation in the coastal areas, overfishing, harvesting juveniles, river water pollution, climate change, upstream dam construction, and cross-border smuggling of hilsa. These have both compromised management strategies and disincentives and put further pressures on hilsa fishery. These pressures include habitat destruction and biodiversity loss, which in turn result in reduced hilsa catches, poverty, malnutrition, stakeholder conflicts, insecurity, and social tensions.

Table 4 Drivers and pressures in hilsa fishery

Rank	Issues	Category	Effects	Solutions	Alternatives
1	Use of illegal fishing gear	Human	Reduced hilsa catch; loss of biodiversity	Enhanced compliance with regulations	Awareness, empowerment, and participation Alternative income-generating activities
2	Improved fishing technology	Human	Reduced hilsa catch; loss of biodiversity	Enhanced compliance with regulations	Awareness, empowerment, and participation
3	Population growth and increased number of fishers and non-fishers	Human/ Natural	Reduced hilsa catch; poverty; malnutrition; conflicts and social tensions	Alternative income sources	Education

Rank	Issues	Category	Effects	Solutions	Alternatives
4	Overfishing	Human	Reduced hilsa catch; poverty	Enhanced compliance with regulations and enforcements	Alternative income activities
5	Juvenile and broodstock harvesting	Human	Reduced hilsa catch	Enhanced compliance with regulations and enforcements	Alternative income activities Awareness, empowerment, and participation
6	Imposed ban period	Government	Malnutrition and the debt trap	Compensation-based schemes	Improved financing mechanisms Alternative income activities Allow other fish species to be caught during the ban period
7	Inadequate allocation of incentives by the government	Government	Malnutrition, debt trap, and social tensions	Incentives for the affected stakeholders	Compensation-based schemes
8	Improper fishing regulations and non-compliance	Government	Illegal fishing, debt trap	Enhanced compliance with laws and enforcements	Awareness, empowerment, and participation
9	Dam and barrier constructions	Human	Siltation increased and migratory pattern of hilsa fish effected	Pre-planning and assessment before the establishment	Cooperation among neighboring countries, including India and Myanmar
10	Water pollution and climate change	Human/Natural	Hilsa migration and hindrance for brood hilsa to lay eggs	Enhanced compliance with regulations and enforcements	Awareness, empowerment, and participation
11	Changes in fish migratory routes	Human/Natural	Spawning grounds disturbed; reduced nursery areas for fish fries	Ecosystem-based management	Spatial closure in the mouth of the sanctuary
12	Illegal trade	Human	Increased hilsa selling price in the local market	Enhanced compliance with regulations and enforcements	Awareness, empowerment, and participation

To address these challenges, multi-level responses are recommended to improve the sustainability of hilsa fishery, including social work to enhance social resilience of the fishing community, increased incentives for all fishers and major stakeholders at the ground level, promoting community-supported fisheries, improving the financing mechanism for the fishers, and introducing hilsa fishing-based eco-tourism. A summary of drivers and pressures in hilsa fishery states the problems, categories, effects, possible solutions, and the steps needed for solutions are presented in Table 4. The findings are summarized as approved by the fishers and other stakeholders during the FGDs and ranked according to the importance given to them by interviewees and FGD participants.

4.1.1. Understanding SES Via DPSIR

The concepts of SES and DPSIR have proven to be feasible approaches to identify the challenges of SSFs to determine comprehensive social responses (Ojeda-Martínez et al., 2009). The problems in an SES can be addressed at a social, economic, or ecological level, as well as at a regulatory level through governance and management structures. This requires a societal response from the interested stakeholders of the SES, demonstrating their capabilities to respond to deteriorating situations and come up with the actions to solve problems or mitigate damages (Crépin et al., 2017; EFTEC, 2005). This is also true for hilsa fishery: To make a hilsa fishery SES sustainable, societal responses are necessary. In article I, the participants provided different responses, including proper compensation schemes for the stakeholders, strict compliance, alternative income-generating activities, fisher-friendly credit systems, the use of fishers' local knowledge, awareness, and participation of stakeholders, and transboundary initiatives. All the responses are shown in the proposed DPSIR framework (Figure 4).

Responses within this framework should be environmentally sustainable (nature friendly), economically viable (possible to deliver at a reasonable and a supportable cost), socially desirable (supportive of established cultural identities), and administratively achievable (capable of being carried out by different ministries, agencies, NGOs and governments). In article I, different responses are considered and described as remedies for the harmful effects of impacts on hilsa fishery. In summarizing my research findings in this regard as a whole, I propose several responses (Table 5), listed in order of priority, based on the frequency with which they were mentioned within interviews, the priority given to each by informants when asked in interviews and FGDs, and my field observations within these fishing communities.

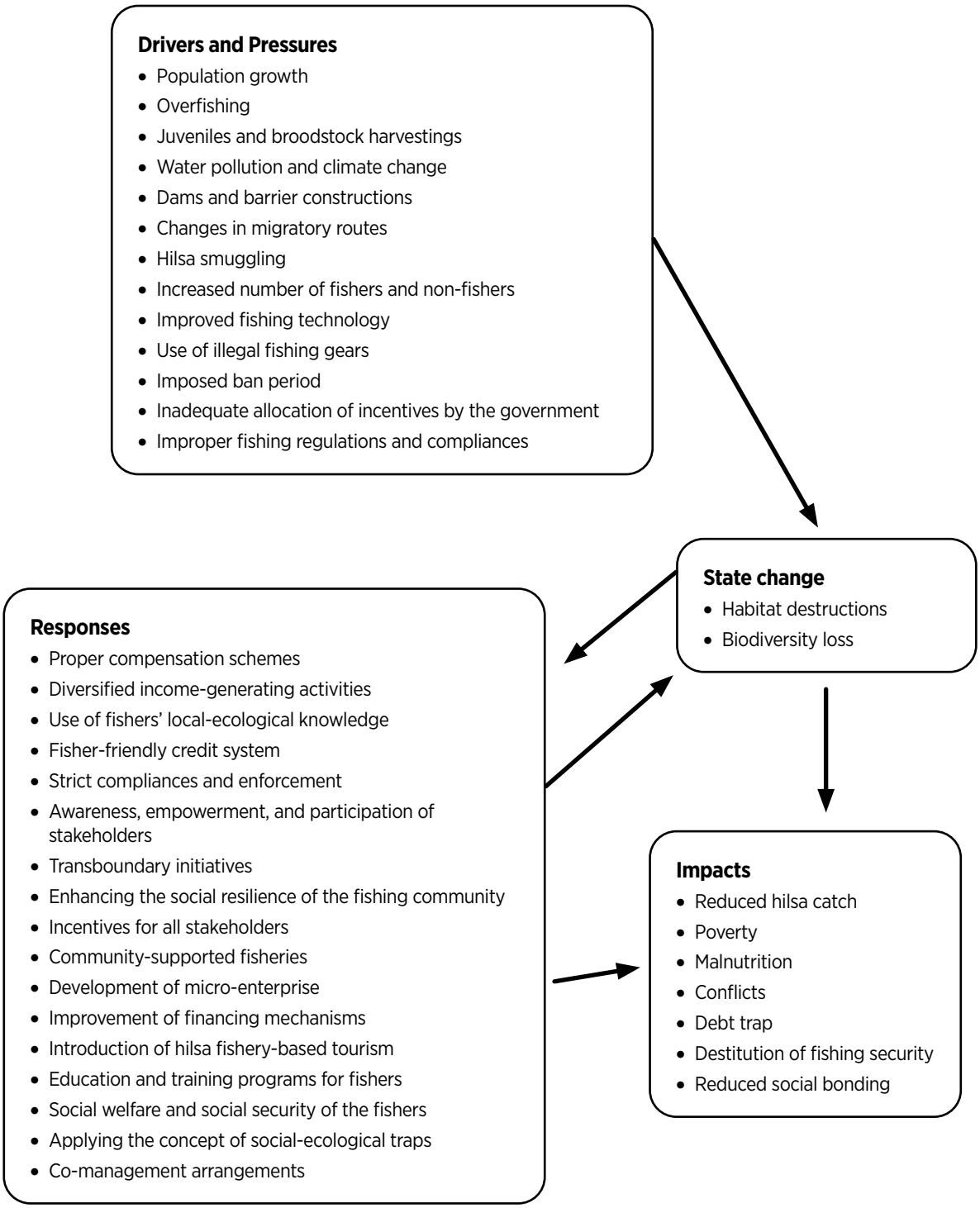

Figure 4 A schematic proposal of the DPSIR framework for hilsa fishery management in Bangladesh

Table 5 Responses and actions for meeting challenges in hilsa fishery

Rank	Responses/Actions	Results/Impacts
1	Co-management	Enhance the social resilience of the stakeholders, power relations among stakeholders, and sustainable fishery management through participation
2	Enhance compliance with regulations/improved enforcement of the legislation	Sustainable hilsa fishery management and conservation of biodiversity in the hilsa sanctuaries; increased trust in the fairness and impartiality of the rule of law
3	Incentives for all stakeholders	Resolve social tensions/conflicts
4	Improved financing mechanism	Remove the debt trap and poverty, alternative income-generating activities, and fishing ban period crisis
5	Compensation-based schemes	Incentives for fishers, conserve biodiversity, fishing ban period crisis, and alternative income-generating activities
6	Education	Create income sources and awareness
7	Breaking the social-ecological trap[5]	Poverty, overexploitation of fishery resources, alternative income-generating activities
8	Awareness, empowerment, and participation	Managing sanctuaries, biodiversity, and conservation regulations, monitoring and policing
9	Social resilience	Overexploitation of fishery resources, alternative income-generating activities, sharing responsibilities to manage fishery and community network
10	Fishing-based tourism	Poverty and alternative income-generating activities
11	Promotion of local ecological knowledge (LEK)	Sustainable fishery management and selection of a sanctuary area
12	Transboundary initiatives	Sustainable fishery management, enforcement of ban period at the same time in Bangladesh, India, and Myanmar
13	Social welfare	Protect fishers (injury, illness, death) and well-being of the fishers
14	Micro-enterprise	Fishing pressure, poverty, debt trap, helpful to buy fishing gears
15	Community-supported fisheries	Debt trap, to buy fishing equipment's and to get a fairer market price for the fish catch

5 This is a concept in SSFs referring to the dynamic interaction between poverty and natural resource use that creates situations considered undesirable in mainstream normative views of development (Cinner, 2011).

The DPSIR framework employed in article I provides an overview of the relations between different aspects of the SES, but not those within the DPSIR categories themselves. In terms of DPSIR terminology, social and economic developments (driving forces, D) exert pressures (P) on the environment, and, consequently, the state (S) of the environment changes. This leads to impacts (I) on ecosystems, human health, and society, which may elicit a societal response (R) that feeds back on driving forces and directly pressures the state or impacts, via various mitigation efforts, adaptations, or remedial actions (Smeets & Weterings, 1999). In article I, I advance the DPSIR framework by connecting specific solutions (responses) to particular problems (pressures) (Table 5). In article I, there is also a general tradeoff between providing an overview of DPSIR on the one hand (Figure 4) and providing a more detailed view of the relationships between specific items within these categories. Given that I identified more than 10 plausible responses, it could be constructive to assess which responses support or contradict each other. Future research could also assess possible synergies and incompatibilities between responses in the DPSIR framework depending on the surrounding societal trends and realities. However, in article I, I opted to provide a more general overview of DPSIR in hilsa fishery—important in itself because the DPSIR framework has, to date (and to my knowledge), not been systematically applied to hilsa fisheries.

4.1.2. Implications for Co-management via SES and DPSIR

The SES framework provides a useful theoretical tool to describe the complexity of the interactions between human and natural systems in hilsa fishery. By combining the SES and DPSIR frameworks, I gained a more comprehensive understanding of issues related to environmental governance and sustainability that are relevant to a wide range of actors, including the local community, representatives of government administration, NGOs, and academics. Using the SES framework, I identified the components of that system and their articulation with hilsa fishery. It was useful to employ the SES framework before the DPSIR framework to have a better understanding of the complex issues and actors involved in hilsa fishery, thus facilitating a complete assessment of the interactions between drivers, pressures, state, impact, and response, facilitating the proposal of implementing the adaptive co-management plan (Lewison et al., 2016).

Co-management must understand how the SES functions and what aims its management sets out to achieve. Thus, there must be an interactive relationship between the SES and co-management. DPSIR, in turn, is a simplified causal model, but it can help identify solutions (such as co-management) and policy responses. By providing a better understanding of the problems involved, it also improves the quality of the solutions. DPSIR highlights responses' capacities to

cope with drivers, to decrease pressures, to restore steady states, and to mitigate impacts. Thus, co-management could be designed according to the linkages of responses to other dimensions in the DPSIR framework. This is a simplified idea of causal relations, but it could concretize different types of objectives for co-management and the SES to be governed. However, within this rather straightforward view, social issues, including power, need to be considered in more depth.

4.2. Enhancing Social Resilience of the Coastal Fishing Communities (Article II)

Article II (Mozumder et al., 2018) of this dissertation sets out to provide a better understanding of the dynamics of social resilience, to fill a gap in theoretical and empirical research regarding the social resilience of natural resource-dependent local communities, and how the over-exploitation of natural resources relates to problems in social resilience. This article applies the concepts of SES, social resilience, and co-management in outlining the qualitative data from the fishing villages in southern Bangladesh and framing its interpretation. The findings indicate that while the establishment of hilsa sanctuary areas has enhanced the previously low ecological sustainability of local small-scale fishing, the management of this program has challenged the social resilience of hilsa fishers by creating new inequalities in the distribution of power. Furthermore, privilege refers to how seasonal fishing bans are enforced and compensation for income lost during the ban periods is distributed. Based on the findings of article II, specific measures are suggested for strengthening social resilience at the local level, including building community networks, developing community infrastructures, updating existing rules and regulations, providing alternative means of generating income for fishers during the crisis periods (natural disasters and fishing ban periods), and more active sharing of responsibility between stakeholders and government for hilsa fishery management. These findings are also applicable to understand the issues beyond rules and regulations that co-management systems need to address to be successful and to enhance the function of co-management arrangements in improving social resilience within resource-dependent communities. A summary of the results is presented in Table 6.

Table 6 Challenges to social resilience and fishers' suggestions for addressing them

Challenge for social resilience	Empirical description of the challenge	Solutions to address the problem
Food security	Seasonal bans on hilsa fishing, insufficient and delayed rice distribution as a diet supplement, and incentive to comply with the regulations cause seasonal food insecurity for hilsa fishers	Alternative livelihood options, sharing responsibilities with the government, use of local ecological knowledge, fishing for other fish species and improving fishing rules and regulations through community consultation
Poverty and debt cycle	Fishers' access to the formal credit markets is limited. Fishers depend on the informal credit (dadon) system to buy fishing gear and boats. This system requires fishers to sell their catch directly to their creditors, thus preventing them from getting a fair market price for the fish.	Alternative livelihood options, building community networks (a cooperative bank), and the introduction of micro-credit facilities
Employment and migration	Due to reduced catches, several fishers who depend on hilsa fisheries as a source of livelihood have become unemployed and migrated to nearby cities.	Alternative local livelihood options, developing community infrastructures and community networks.
Social Tensions	Distrust and mutual accusations of illegal fishing between those with motorized and non-motorized boats; pressures to fish illegally to pay off loans from dadondars having negative impacts on hilsa sanctuaries; corruption in incentive distribution practices	Sharing responsibilities as a form of co-management, use of local ecological knowledge, and opportunities for micro-credit facilities

4.2.1. Resilience and the SES, with Foci on Social Resilience and Co-management

SER is the capacity to adapt or transform in the face of changes in SESs, particularly for unexpected turns related to the structures people depend on to support their well-being (Folke et al., 2016). Adaptability refers to human actions that sustain, innovate, and improve development on current pathways, while transformability is about shifting development into new pathways and even creating novel ones (Folke et al., 2010). One of the fundamental differences between social and ecological resilience is that in social resilience, the adaptive capacity in question relates to the ability of humans to influence their circumstances intentionally (Nelson et al., 2007). Thus, understanding social resilience calls for explicit attention to power relations and the unequal distribution of agency (Davidson, 2010). Understanding how social resilience can be conceptualized and operationalized is essential for research on the sustainability of SESs and resource-dependent communities (Maclean et al.,

2014). Furthermore, knowledge of the properties of social resilience can help managers and resource users design policies that minimize adverse impacts on people and maximize the sustainability of the goods and services derived from the ecosystem (Maclean et al., 2014).

Recent research on SER has grown progressively, but ecological and social resilience is not entirely clear (Berkes, 2017). However, a resilient ecosystem could be expected to support resilient communities and vice versa, but the interaction is not straightforward (Islam et al., 2018). For instance, social outcomes of resilient ecosystems are often mediated by several factors such as communities' resources, individuals' operationalized rights, and access to the environment (Finkbeiner, 2015). Ecosystem outcomes are also dependent on social factors such as tenure within management regimes, markets, and technological factors Cinner et al., 2016). Examining this intricate link between social and ecological resilience will require more in-depth consideration of social institutions (i.e., the formal and informal rules governing human behavior; (Schlager & Ostrom, 1992), as well as the roles of power and politics in enabling individuals, households and communities to benefit from ecological resilience (Leach et al., 1999).

Social resilience in an SES can be enhanced through co-management of the resources in question. Co-management can serve to improve the social resilience of local communities, enabling them to have more power and control over decisions regarding how the natural resources they depend on are to be used (Tompkins & Adger, 2004). To achieve resilient co-management systems, two types of responses are to be considered: coping mechanisms and adaptive strategies (Olsson et al., 2004). Coping mechanisms are short-term emergency responses to abnormal seasons or years; adaptive strategies are ways in which individuals, households, and communities change their production systems and modify local rules and institutional structures to secure livelihoods (Kalikoski & Allison, 2010). Co-management works best if the local community focuses on formulating a system of rights and regulations.

In contrast, the government focuses on formulating a legal framework to back up such a system (Carlsson et al., 2012). The social resilience of local fishery-based communities can be restored through co-management with different stakeholders. A discussion of the following issues will help to understand the process of enhancing social resilience through co-management initiatives.

Incentives and Institutional Arrangements. While fishery sanctuaries are a useful management tool, they can also negatively affect dependent communities socially, economically, culturally, and politically (Jentoft et al., 2012). Although fishers perceived the positive ecological impacts of sanctuary establishment because they rely on the fishery for their livelihoods, their self-interested behavior is often contrary to conservation goals. Fishers who belong

to an organization such as a cooperative, however, are more inclined to consider sanctuaries as a positive move by the government. Such an attitude is related to the fact that members of social organizations may be outspoken and involved in management. Thus, they receive relevant knowledge and feedback on sanctuaries and find the opportunity for social interactions with other stakeholders. Therefore, it is recommended that local people, including fishers, be enabled to participate more in co-management to increase the legitimacy of conservation efforts from their perspectives, thereby enabling better socio-economic and ecological outcomes (Bennett & Dearden, 2014). The success of conservation measures is highly dependent on delegating responsibilities to communities (Pita et al., 2010). This type of restructuring can produce multiple benefits for the existing hilsa sanctuary management system. First, hilsa sanctuaries exist in high population density basins, and thus resident fishers can easily watch/patrol these areas. Second, if fishers and other stakeholders in the value chain, such as fish traders and money lenders, shoulder some responsibility for managing sanctuaries, they are less likely to encourage the violation of the conservation regulations. For these reasons, the engagement of all stakeholders in monitoring and policing activities should be considered, along with a compensation scheme for those doing so. In addition, to make the sanctuaries more successful, various social welfare and local social development programs should aim to create new economic opportunities for fishers and their families.

An incentive-based hilsa conservation program has three primary functions: raising awareness of sustainability issues, providing supplementary food to fisher households as an incentive for cooperation, and supporting AIGAs (Islam et al., 2016). As observed in the present study, the incentive distribution is not sufficiently equitable because non-fishers also get incentives, and the value of incentives is not adequate to keep families fed. It is often the case that small-scale fishers are disproportionately negatively affected in the short term by limits on their harvests, due to a massive reliance on fishing and limited alternative livelihood options (Sunde & Isaacs, 2008). Hence, schemes need to carefully assess "who loses and who wins" and estimate as accurately as possible any loss of earnings arising from measures restricting access to resources (Engel et al., 2008).

Fishery management regulations cannot be successful without support from the fishers. Otherwise, fishers will frequently break the rules and make the management of fisheries more expensive (Hanna, 1995). The government uses a top-down management system in many SSFs with little or no participation by fisher groups (Purcell & Pomeroy, 2015). The intentional transformation of governance institutions may be a necessary step toward the longer-term goal of resilient livelihoods. This will require a shift from the current top-down model toward one of adaptive governance—utilizing a range of interactions

between actors, networks, organizations, and institutions emerging in pursuit of sustainable conditions for SESs (Chaffin et al., 2014).

Opportunities for Diversified Income. Alternative livelihood options can be arranged for the fishers during lean periods and times when fishing is banned for purposes of conservation. This can help fishers move away from unsustainable harvesting by making them less dependent on such practices, as well as directly alleviating some of the poverty in fishery regions (Allison & Ellis, 2001). Studies on employment, labor, productivity, and income in SSFs have found that coastal fishers in Bangladesh have the lowest level of education within this profession (Sunny et al., 2019). The findings in article II support this conclusion. This factor also creates a barrier to their procuring decent alternative jobs in their locality. Fishing households that do have financial assets and liquid capital at their disposal have begun fishing more intensely and for more fish species, actions that add to the problems of more impoverished families by further degrading fishery resources. Consequently, poorer fisher households have either opted for coping approaches (loans, mortgages, asset liquidation, changing food habits) or migration in search of alternative livelihoods (Nayak et al., 2014). Having local diversified income opportunities would add a great deal of stability to their lives.

Financial Assistance. Informal credit (dadon) from a fishing entrepreneur (aratdar) is the only source of financing currently available to poorer hilsa fishers, as their business is very capital-intensive and most lack the collateral necessary to facilitate a loan from a regular commercial bank (Islam et al., 2016). They also tend to fear the awkward and lengthy processes of applying for institutional credit. From there, excessive pressure to pay off their informal loans from the money lenders compels many marginal fishers to engage in illegal and unsustainable fishing practices. Natural term institutional credit facilities that offer low-interest rates without a requirement of collateral are particularly needed among hilsa fishers. Microcredit can be an essential tool in this regard. By extending small, collateral-free institutional loans to members of a jointly liable group of poor workers to enable self-employment and income-generating activities (Ahlin & Jiang, 2008), microcredit helps diversify livelihoods of the people who are entirely or partially dependent on a shared pool of resources for their livelihoods. (Develtere & Huybrechts, 2005).

Participation and Local Knowledge. Fishery management requires implementing such measures as monitoring, control, and surveillance (MCS) of closed areas during closed seasons. Without the involvement of communities, it is impossible to effectively implement these measures to protect fishery resources (Dungumaro & Madulu, 2003). In article II, hilsa fishers and other stakeholders

also stated their positive orientation toward participating in the co-management process to improve the sustainability of hilsa fishery and enhance their social resilience. Small-scale coastal fishers regularly observe the local marine environment when fishing and, hence, are attuned to changes in the abundance of catchability of their target species (Johannes et al., 2008). Local fishers are often the first to notice changes in species' abundance (Silvano & Jørgensen, 2008). Thus, there have been recommendations to integrate local and traditional knowledge into fishery management and conservation programs (Beaudreau & Levin, 2014). Traditional and regional experience has led to the "discovery" of ecological or behavioral phenomena previously unknown to scientists. For example, indigenous peoples in the Western Solomon Islands pinpointed population changes of Bump head parrotfish (Bolbometopon muricatum) and provided useful conservation strategies for its protection (Aswani & Hamilton, 2004). Several case studies have shown that local knowledge has a vital role to play in the better management of Bangladesh's inland and coastal fisheries, as does sharing experiences among communities (Mozumder et al.,2018; Khan et al., 2012). Communities can agree on and implement actions to improve fishery management. In the long term, this endeavor requires a framework of government support for local community initiatives, especially when they are being threatened by local elite interests (Sultana & Thompson, 2008). Article II reveals that hilsa fishers have immense local knowledge concerning hilsa's breeding periods, feeding habits, fishing grounds, and migration patterns. Such knowledge should be included in the co-management process.

4.3. Governance and Power Dynamics in a Small-Scale Fishery (Article III)

Article III (Mozumder et al., 2020) looks at the hilsa fishery case study in terms of governance and power dynamics and the relevance of these for the sustainable management of the SES. The analysis in article III is based on the power cube framework. The main findings are as follows.

Present Hilsa Fishery Governance. The analysis noted a significant power imbalance in the present hilsa governance structure, with some stakeholders exercising more power than others, sidelining fishers, and encouraging more non-compliance in terms of illegal fishing that ultimately harms both hilsa fishery and its users. During the in-depth interviews and FGDs, participants shared their perceptions concerning the loopholes in the present hilsa fishery governance. Participants summarized the reasons for non-compliance with fishery regulations as being mainly due to poverty among fishers, patron-client relationships with intermediaries, irregularities in supplementary food

distribution, limited opportunity for alternative livelihoods during the fishing ban periods, availability of illegal and destructive fishing gear, irresponsible greed for larger catches among some (mainly affecting broodstock), corruption within law enforcement agencies, and hilsa fishers being excluded in decision making.

Value Chain and Power Relations. Fishers, assemblers, processors, traders, intermediaries, transporters, and day laborers are involved in hilsa fishery. The endeavor is capital intensive, most fishers cannot afford to go fishing at their own expense, and fishers work without collateral, meaning they do not have access to standard bank loans. Thus, an informal loan (dadon) from a fish trader (aratdar) is the only available financing. In return, the aratdar can buy the catch at a lower-than-market-value price. In a typical situation, a mohajan (owner of a boat and fishing nets) uses this dadon system to purchase and maintain his productive assets. Nevertheless, the mohajan often loses money by selling his catch at a lower price and paying a commission to the aratdar. A mohajan usually works as the captain (majhi) of his boat or can hire another experienced fisher as majhi. Crew members are called malla or vaghi—general laborers in operation paid either a day wage or with a share of the proceeds from the catch's sale.

During the in-depth interviews in study area 1, hilsa fishers stated that the power relations based on wealth and dependency among the actors in the value chain (most powerful to least powerful) are as follows: aratdar → mohajan → majhi → malla/vaghi. Given that the aratdar provides loans to the mohajan, the aratdar can be considered the most powerful in the chain. There was a similar value chain in study area 2 and confirmed in the FGDs. Although the benefits of hilsa fishery are unevenly distributed among different groups along the value chain, aratdars as investors are key players in capital-intensive hilsa fishery in both study areas. The primary limitations of hilsa fishers are a lack of brokering power and market information at the market level.

Power Relations Among Stakeholders. In addition to the main stakeholders in the hilsa fishery value chain described above, there are also other stakeholders involved in hilsa fishery management, local government administration personnel (Upazila Nirbahi Officer [UNO], Upazila Fishery Officer [UFO], Coastguard, and Police), NGOs, local political leaders, local government representatives (members/chairman), transport services, net traders, wholesalers (paikar), ice traders, diesel oil merchants, the chief aratdar (in the city of Dhaka), and journalists. All these stakeholders have relations with at least some (not necessarily all) of the other stakeholders, involving multiple power relations (see Figure 5).

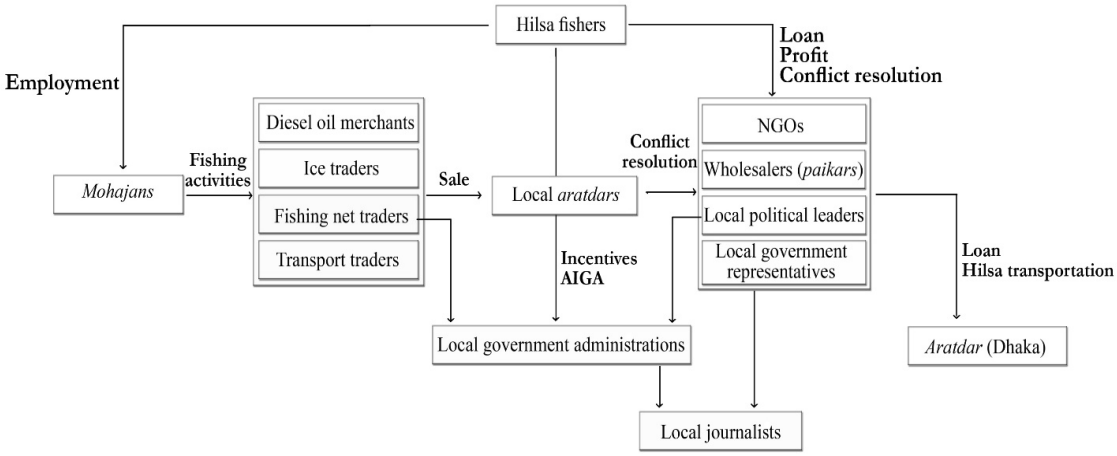

Figure 5 Power relations and service provision among stakeholders in the hilsa fishery value chain and management.

Based on the in-depth interviews and FGDs in study areas 1 and 2, the relationships and power dynamics are summarized as follows. The mohajan has relations with the diesel oil merchants, net traders, ice traders, and transport services to run the fishing boat and preserve the fish for sale to the aratdar. In this case, ice sellers, oil merchants, and net traders have more power than the mohajan, as the latter cannot run his boat without oil or preserve the hilsa without ice. Second, the aratdar has relations with the NGOs and wholesalers (paikar), as aratdars get monetary support from them. Aratdars also have ties with the local political leaders and local government representatives to solve conflicts among crew members in hilsa fishing boats. Hence, local government representatives and local political leaders have power over the aratdar. Third, net traders have relations with the local government administration because it enforces the law and seizes illegal fishing nets, such as the monofilament gill nets that are still commonly sold. In addition, local government representatives depend on local political leaders, who have power to influence local people and fishers during the election period (vote bank). The local government administration is the most powerful because it has judiciary power to implement compliance measures and address management issues. Local political leaders and local government representatives (union parishad members and chairman) work on the guidelines given by the local government administration personnel.

Besides, wholesalers (paikar) have a relationship with the prominent aratdar in Dhaka for more substantial loans, with the local aratdar buying hilsa from them, and transport services to transfer hilsa to the aratdar in large Bangladeshi cities including Dhaka. Local journalists have relations with the local stakeholders (political leaders, local government representatives) involved with hilsa fishery

and local government administrative personnel as journalists publish updates of the law and enforcement measures related to hilsa fishery management. Finally, general hilsa fishers (vaghi) have relations with: the mohajan, to obtain work on a boat, catch hilsa fish, and to get a profit from the catch; NGOs, to get loans during times of crisis, including the fishing ban period; local leaders, to solve conflicts with their mohajans; local government representatives, to resolve social disputes and to be included on beneficiary lists to collect incentive pay for not fishing during the ban period; and local government administrative personnel, to get incentives and favors for AIGAs.

Power Dynamics Bearing on the Execution of Hilsa Incentive-Based Conservation. Hilsa fishers complained about the distribution of incentives for compliance with regulations in the form of food supplements. There was a widespread perception in study area 1, in particular, that corruption among local government officials was keeping them from getting all of the rice that they were entitled to and that delays caused by bureaucrats bargaining over the rice were causing their families to go hungry for extended periods.

Power Spaces: Closed Space. It was evident during the in-depth interviews and FGDs that stakeholder participation is mostly lacking, even though it is essential to have all stakeholders involved in the fishery's sustainability. Participants in the FGDs claimed that they urged the local government administration to include only genuine hilsa fishers in the incentive payment beneficiary lists. Nevertheless, some deserving fishers were excluded, and some non-fishers were given benefits intended as incentives not to fish during the ban periods through favoritism.

Power Spaces: Invited Space. Several NGOs and the GoB have recently made initial efforts to widen the participation of hilsa fishery stakeholders to improve the sustainability of hilsa fishery. For example, to further enhance the annual fishery production figures, the DoF and WorldFish have been jointly implementing "Enhanced Coastal Fisheries in Bangladesh (ECOFISH-Bangladesh)," a USAID-supported project (2014–2019). The project supports the DoF and local communities in establishing a science-based "adaptive co-management" strategy that focuses on protecting brood hilsa and juvenile fish, preventing the use of illegal fishing gear, and promoting overall ecosystem resilience to all stakeholders.

Power Spaces: Claimed/Created Spaces. When asked during FGDs what empowerment would mean to them in practical terms, respondents, especially hilsa fishers, spoke of electing representatives who would fairly and responsibly

represent their interests, being able to bargain for better prices for their fish outside of the control of the local aratdar, and being able to buy their equipment through government-subsidized credit systems.

Forms of Power: Visible Power. In this study, it was noted that a general hilsa fisher (vaghi) gets work through his or her relationship with a mohajan who captains a boat and divides the profits of the catch with the crew members. In interviews, however, vaghis claimed that they are never actually told what the selling price of the catch is in the market: The mohajan has the power to decide how much to pay them, and vaghis have no bargaining power in the matter. They cannot take their individual shares of the catch and try to sell those fish by way of other intermediaries. Mohajans can also use their political influence with lenders and government officials to quell dissent in their crew: Someone who argues over wages may be threatened with exclusion from access to loans or food supplements during the off-season. For a vaghi then, the mohajan is the primary manifestation of visible power.

Forms of Power: Hidden Power. It was found that local aratdars have a certain degree of hidden power in their dual role within hilsa fishery management. During an in-depth interview with an aratdar, he stated that he supports seasonal restrictions on hilsa fishing (not to catch juveniles and broodstock) imposed by government and prohibitions against the use of monofilament gill nets. Yet, hilsa fishers in the same area claimed that by refusing to re-negotiate loan payment schedules to take seasonal restrictions into account, the aratdar effectively forces them to fish illegally.

Forms of Power: Invisible Power. The present study found that female fishers have a specific invisible form of power in hilsa fishery. FGDs revealed that increased involvement of women in fishery management could lead to increased household well-being in viable alternative income-generating activities for the fishers and their family members being established during the fishing ban seasons. These included nets making, cage aquaculture, poultry rearing, small dairy ventures, plant nurseries, gardening, and handicrafts. A few fisherwomen were also involved in AIGAs. They felt that they could play a more substantial indirect role in conserving hilsa by supplementing their family income by other means.

To overcome the challenges described above, a co-management system was proposed to reduce power asymmetry among hilsa fishery stakeholders and ensure effective hilsa fishery governance. The findings suggest that the recognition of power dynamics has substantial implications for the planning and implementation of co-management and the long-term hilsa fishery sustainability.

4.3.1. Power Relations and Co-management

Article III applied the power cube framework to analyze governance and the power dynamics of hilsa fishery. The findings revealed significant power differences among various actors in and around hilsa fishery. In hilsa fishery management, the dominant actors in decision making are not hilsa fishers; they are others who hold political power. The DoF, local government administration and representatives, law enforcement authorities, and aratdars all have some form of power that operates in closed spaces, which they use to create rules and make decisions that adjudicate all fishery functions, from catch to consumer.

These findings further revealed that the current hilsa governance structure is not well balanced, because some actors are exercising more power by closing spaces or creating spaces, thereby sidelining basic fishers and encouraging more non-compliance in terms of illegal fishing, thus ultimately bringing harm to both the fishery and its users. The primary reason for non-compliance with fishery regulations was desperation caused by poverty among hilsa fishers. Given that they cannot support their families while abstaining from fishing during ban periods, they take high-interest loans from an aratdar, and this aratdar, along with his regular mohajan, compels them to break the rules and fish illegally. The aratdar and mohajan are themselves, power holders, with political connections, and they can sometimes manipulate law enforcement and policy implementation through bribes and other forms of corruption. In fishing households that try to abide by the rules, government compensation for wage loss often arrives late, and corrupt officials tend to skim off part of the amount that has been theoretically allocated to them.

Despite several problems with hilsa fishery governance, the present study attempted to identify some possible means of improving the situation and realizing the goals of good governance initiatives in hilsa fishery. Participants urged a complete ban of monofilament gill net production in local industries. Official corruption needs to be stamped out, especially among law enforcement and support distribution authorities. Proper and fair incentive support must be paid to those who are unable to work during periods when their livelihood is banned. Finally, credit must be made more readily available for buying fishing boats and gear and enhancing opportunities for alternative livelihoods.

Co-management has mixed outcomes because its context, role, efficacy, and success vary widely (Chuenpagdee & Jentoft, 2007). For example, such practices may have some undesirable social and ecological outcomes such as the risk of elite capture and dominance by the powerful, creating incentives for over-exploitation that may increase social inequality and create other conflicts (Wilson et al., 2006). Furthermore, sharing power and responsibility are essential characteristics of co-management, with the enablement of legislation, participation, representation,

and empowerment being seen as critical for success (Sandström et al., 2014). Based on the case study here, article III proposes that the issues described below should be considered regarding the equalization of power relations among the stakeholders, to better initiate and implement co-management arrangements in hilsa fishery governance.

Power-sharing can be arranged at different levels according to the extent of the resource-using community's participation in decision-making processes (Ho et al., 2015). This can range from the lowest level of "informing," where the resource users are passive actors in co-management and are informed about what government has decided to do, to the highest level of partnership, where genuine political power is delegated to resource users (Pita et al., 2010). Equal power sharing only occurs when the resource users have the same rights as the government in making decisions on resource management (Adger et al., 2005).

Fishery management involves balancing the competing demands of all fishery resource users. Conflicts among fishery stakeholders arise due to differences in power, interests, values, priorities, and manner of resource exploitation (Murshed-e-Jahan et al., 2014). Conflicts also emanate from institutional failures in managing fisheries and enforcing laws and regulations (Njaya, 2007). The lack of conflict management mechanisms in the hilsa fishery case relates to problems that reduce the sanctuaries' effectiveness, bringing about rampant non-compliance among the users. It also compromises the legitimacy of the conservation measures, as powerful actors such as aratdars are often involved in illegal fishing but do not face any penalties for such, which makes general fishers resentful towards conservation measures.

Most hilsa fishers lack the means to operate in their profession without outside capital. Thus, to continue fishing, they must seek credit either from NGOs or the local aratdars, with their restrictive terms and high-interest rates. From the present study, it was evident that the local aratdar has immense power. However, if fishers have the opportunity to sell their fish to another aratdar at a better price by bargaining, rather than to the same aratdar they are bound to by a credit contract, the power of the aratdar will diminish. He will be more likely to compromise with the fishers and offer a better price for their fish.

Most of the respondents consider their income from fishing to be quite limited. Fishers must be provided with adequate compensation for their financial losses, enabling them to meet their basic subsistence needs during periods when fishing must be temporarily banned. It is evident from the present study that hilsa fishers' fish illegally or use destructive fishing gear not because they want to, but because they feel it is the only way they can survive. More robust schemes to enable local fishers to lift themselves out of poverty are needed.

Fishers' traditional knowledge, experience, observations, and opinions should be integrated into fishery management policies and their implementation. As an

example, such knowledge may help set the dates for hilsa fishing ban periods and the geographical boundaries for fish sanctuaries and in formulating other fishery policies. A summary of the main findings per article is presented in Table 7.

Table 7 Summary of the articles and findings

Components of Article	**Article I**	**Article II**	**Article III**
Title	Understanding Social-Ecological Challenges of a Small-Scale Hilsa (*Tenualosa ilisha*) Fishery in Bangladesh	Enhancing Social Resilience of the Coastal Fishing Communities: A Case Study of Hilsa (*Tenualosa ilisha*) Fishery in Bangladesh	Governance and Power Dynamics in a Small-Scale Hilsa Shad (*Tenualosa ilisha*) Fishery: A Case Study From Bangladesh
Aims	To understand the social-ecological challenges of a small-scale fishery	To understand the dynamics of social resilience, including the implications of hilsa over-fishing on social resilience and what is needed to enhance the social resilience of the coastal fishing communities	To delve into governance and power dynamics that are considered essential to manage sustainably a small-scale fishery
Components of Article	**Article I**	**Article II**	**Article III**
Research questions	What is the present state of hilsa fishery? What are the driving forces and pressures in hilsa fishery? What are the impacts of driving forces, pressures, and changes of state on local livelihood prospects? What are the possible responses to increase the sustainability of hilsa fishery?	What are the implications of hilsa over-exploitation on social resilience? Can co-management enhance social resilience, and if so, how?	How did the current governance systems in hilsa fishery develop and operate along with the Padma–Meghna River systems in Bangladesh? How is power exercised/distributed, and how does it discriminate among the stakeholders in hilsa value chains? What spaces and forms of power exist in the fishery, and how do they play out among different groups of stakeholders in each of these spaces?
Theory	Social-ecological system and driver-pressure-state-impact-response	Social-ecological system, social-ecological resilience, and co-management	Power cube
Data collection methods	Qualitative (in-depth interviews and focus group discussions)	Qualitative (in-depth interviews and focus group discussion)	Qualitative (in-depth interviews and focus group discussions)
Data analysis methods	Thematic	Content	Thematic
Main findings	This article provides updated information regarding the status of Bangladesh's hilsa fishery from a social-ecological perspective. This information reveals many problems that hilsa fishery is facing, and suggestions are offered as on how to make hilsa production more sustainable and improve fishers' socio-economic situations.	While the establishment of hilsa sanctuary areas has enhanced the previously low ecological sustainability of local small-scale fishing, the management of this program has challenged the social resilience of hilsa fishers by creating new inequalities in the distribution of power and privilege, in terms of how seasonal fishing bans are enforced and compensation for income lost during the ban periods is distributed.	The analysis displayed an imbalance in the present hilsa governance structure, with some stakeholders exercising more power than others, sidelining fishers, and encouraging more non-compliance by illegal fishing that ultimately harms both the fishery and its users.

5. CONCLUSIONS AND A WAY FORWARD

5.1. Theoretical and Practical Contributions

This thesis is composed of three articles in which I have examined the SER of an SSF from theoretical and empirical perspectives. This thesis contributes to a growing body of literature examining SSFs among rural communities in coastal districts of Bangladesh, particularly regarding hilsa fishery. In the early stages of this research, my literature review of key concepts and frameworks revealed a need to improve and further expand existing theoretical concepts and typologies in the SER of small-scale hilsa fishery in Bangladesh.

The main goal of article I was to determine how to make hilsa production more sustainable and improve fishers' socio-economic situation with the help of the DPSIR framework and by considering hilsa fishery as an SES. Article I contributed by summarizing and visualizing the cause–effect interactions between human pressures and environmental components in a manner familiar to fishery managers and policy-makers using the DPSIR framework as proposed (Figure 4). It is anticipated that this may help to bridge the gap between research and decision-making in hilsa fishery. In article I, I opted to provide a more general overview of DPSIR in hilsa fishery, which is essential in that the DPSIR framework has, to date and to my knowledge, not been systematically applied to hilsa fishery.

In article II, I applied concepts of an SES, social resilience, and co-management to outline qualitative data and frame its interpretation. Article II contributed to an enhanced understanding of crucial issues to be considered as part of co-management approaches to facilitate sustainability and social resilience among hilsa fishers in Bangladesh. Article II also laid some necessary foundations for a social resilience framework by pinpointing key issues underpinning social resilience beyond a pure focus on rules of environmental management, usually at the discussions of co-management literature.

Article III considers the hilsa shad (T. ilisha) fishery of southern Bangladesh as a case study regarding governance and power dynamics at play in an SSF, and the relevance of these for the sustainable management of coastal fisheries. The analysis here is based on a power cube framework along three power dimensions (levels, spaces, and forms) in Bangladesh's hilsa fishery. To my knowledge, no previous studies in hilsa fishery management that have applied this framework. This framework contributed to some theoretically relevant and interlinked conclusions. First, the power cube application revealed subtle power relations—occurring among a wide variety of actors—that are not self-evident. In this study,

I tried to include a variety of actors in and around hilsa fishery and pinpointed crucial issues in the power relations among these actors. Second, this analysis led to the conclusion that power relations are very asymmetrical and not equal, least of all for poor fishers. Third, this finding led me to seek answers as to why the fishers remain without power. There are also dynamic issues at play behind persisting power relations. While I focused on Bangladesh's hilsa fishery, the operationalization of the power cube, as demonstrated in the present paper, can also be applied to other studies to reveal subtle ways in which asymmetrical power relations are manifested in the realities of local communities and actors that are dependent on the same natural resources.

Overall, this thesis provides state-of-the-art knowledge on the status of small-scale hilsa fisheries, existing management approaches, their constraints, and challenges, as well as the potential for enhancing social and ecological resilience through addressing current challenges. It is anticipated that these findings will help policy-makers and local government officials to take necessary actions to support new systems of hilsa fishery management, thereby improving the livelihoods of hilsa fishers and enhancing ecosystem health. These findings can have a direct impact on hilsa fishing communities, and they can serve as an instructive example for other fishing communities, both in Bangladesh and elsewhere.

5.2. Policy Implications and Recommendations

Fisheries around the world are facing a range of challenges and lack robust and careful management. Anthropogenic disturbance levels on ecosystems and fisheries are likely to have a continuous negative impact on biodiversity and fish stocks. Therefore, fishery management authorities need to be both efficient and effective in working toward long-term sustainable ecosystems and fisheries, while also being resilient regarding political and socio-economic pressures. Hilsa constitutes the most critical coastal and marine fishery in Bangladesh. Considering hilsa fishery's economic, social, and cultural values, the government has taken several initiatives, including the establishment of six sanctuaries in the Padma–Meghna River habitats. These initiatives have certainly enhanced the ecological resilience of the hilsa fishery system, but they have also had some negative implications for the social resilience of hilsa-dependent communities (article II). Due to fishery closures and fluctuating catches from small-scale hilsa fisheries in the sanctuary areas, hilsa fishers are today facing many social consequences and becoming less socially resilient.

Article I indicate that SES and DPSIR frameworks are feasible approaches to identify the challenges of SSFs to determine comprehensive social responses.

In addition, to ensure productive and sustainable fisheries, it is essential to understand the complex interactions among biology, environment, politics, management, and governance (Nilsson et al., 2019). This dissertation also reveals an imbalance in the present hilsa fishery governance structure, with some stakeholders exercising more power than others, sidelining small-scale fishers, and encouraging increasing levels of illegal fishing that ultimately harm both the fisheries and those dependent on them (article III). The results suggest that the recognition of the analyzed power dynamics has substantial implications for the planning and implementation of management and the long-term sustainability of hilsa fishery. If managed efficiently, increased hilsa production would boost fishers' resilience and subsistence-based livelihoods, including their social identities and cultural experiences. The findings from this study have led to some relevant policy recommendations that could potentially increase the SER of hilsa fishery, including the involved stakeholders.

Co-management Arrangements. Co-management can be a way of refining the social resilience of local communities, enabling them to have more power and control over decisions regarding how the natural resources they depend on are to be used (Tompkins & Adger, 2004). Due to fishery closures and fluctuating catches from hilsa fisheries in the sanctuary areas, hilsa fishers are facing many social consequences, and they are becoming less socially resilient. The government should take steps to initiate and implement co-management arrangements in the hilsa sanctuaries areas with the help of all stakeholders, including the international and national donor agencies. Such initiatives will build sustainable fisheries and help to cope with the various social problems in these regions.

Legal Framework. There is an urgent need to form a concrete legal framework for hilsa fishery management that would ensure the well-balanced participation of all stakeholders with the fishers and fisherwomen's direct involvement.

Transboundary Initiatives. Hilsa is a transboundary fish because it migrates through the rivers of Bangladesh, India, and Myanmar, and it is harvested in the Bay of Bengal by all three countries (Islam et al., 2016). Millions of fisherfolk are engaged in hilsa fishing in these countries. Therefore, a transboundary initiative for developing a common management policy for hilsa fisheries should be promoted. Such transboundary efforts would help build better governance and non-exploitative, balanced power dynamics in all three countries for the well-being of fishers and the ecosystems. Moreover, joint fishing bans should be coordinated and implemented at the same time in all three countries.

Compensation Scheme. Most of the respondents consider their income from fishing to be inadequate. Fishers must be provided with adequate compensation for their financial losses, enabling them to meet their basic subsistence needs during periods when fishing must be temporarily banned. It is evident in the present study that hilsa fishers' fish illegally or use destructive fishing gear not because they want to, but because it is their only means of meeting their most basic needs. More robust schemes to enable local communities to lift themselves out of poverty are needed.

Enhanced Compliance with Regulations. Regulatory non-compliance and a lack of capacity for carrying out enforcement operations are significant barriers to the effective management of hilsa fishery. The findings from article I demonstrated that economic incentives are an essential factor that influences compliance behavior in small-scale hilsa fisheries. Furthermore, the findings support the observations that most fishers have an opportunistic approach to non-compliance and consider non-compliance behavior in situations where there is a significant economic gain to be obtained, including an assessment of the risk of detection and following (primarily financial) sanctions (Sutinen et al., 1990).

Enhancing the Social Resilience of the Fishing Community. The resilience of both the fishing community (as a social unit) and individual community members are tightly linked to the resilience of the overall SES fishery (Cornell & Hoelting, 2015). The viability of the hilsa restoration project is at risk through over-exploitation, non-compliance with regulations, and conflicts over resource use. It is essential to enhance social resilience to avoid such a situation and sustain the natural resilience of hilsa fishery. The government can take specific measures to strengthen social resilience at the community level, including building community networks, developing community infrastructures, and updating existing rules and regulations. Steps should be taken to provide fishers with alternative livelihood possibilities through need-based training, vocational refresher courses, and microcredit, to keep them from feeling that illegal fishing is the only productive activity available to them.

Incentives for All Stakeholders. There are many groups and categories of people involved in the hilsa value chain (rental boat owners, dadondars, fish merchants, etc.). By controlling the means of production needed by the fishers, they control much of the fishing operations in the sanctuary areas, including the extent to which fishers must operate illegally to continue with that form of livelihood. Thus, if these stakeholders are not motivated to support the principles of preserving biodiversity and maintaining the long-term sustainability of hilsa stocks, in particular, the ecosystem will suffer, regardless of just the fishers'

perspectives on the matter. It is, therefore, essential to discover how these other stakeholders in the hilsa fishing industry are motivated and how to direct their motivation to play a decisive role in biodiversity conservation. The government must also consider these key stakeholders when designing incentive and compensation schemes.

Improvement of Financing Mechanisms. **The fishing villages' financial activities mainly depend upon the availability of credit** at a reasonable cost to enhance production and income (Baylon, 2007). Fishing communities rely on institutional and informal credit sources. Institutional sources are mainly banking/cooperatives, and the friendly credit system includes professional moneylenders (who do not ask what the loan is for) and fish traders (who lend money to secure fish supplies). In Bangladesh, fishers, traders, and intermediaries do not have easy access to formal banks or NGO credit systems, due to too much official paperwork and collateral arrangements. Hence, a well-designed microcredit system for hilsa fishers, considering the seasonal fluctuations in their capacity for repayment, could help gradually liberate these fishers from a cyclical debt trap.

Education and Training Programs for Fishers. Diversification is necessary so that the fishers do not exclusively rely on one type of income. For fishers to survive and increase their household income, more diverse strategies are needed beyond relying solely on the fishing sector (Holvoet & Allison, 2008). The present study also found that alternative income sources can reduce dependency on hilsa fishery and ensure food security for the fishers. However, proper education and training programs are needed for fishers to diversify their income. The government and local NGOs can take initiatives to train the fishers to start businesses and to practice, e.g., aquaculture, farming, and gardening.

Social Welfare and Social Security of the Fishers. Fishing is a particularly hazardous occupation, with a relatively high rate of injury and death (Anderson et al., 2017); hilsa fishing is no exception. Hence, hilsa fishers and their dependents need some form of protection in case of injury, illness, or death. In such cases, the GoB can introduce medical care, sick-leave benefits, unemployment benefits, old-age benefits, employment injury benefits, family benefits, maternity benefits, and invalidity benefits under the Fishermen's Pension and Social Security Benefit Scheme. Such schemes are already running in Sri Lanka (Amarasinghe, 2005). However, getting fishers involved in any project requiring regular payment of a premium seems to be challenging because of the unpredictable nature of fishing incomes. Awareness programs through community organizations like fishery cooperatives can educate the fishers about such schemes.

Empowerment of Women. The economic empowerment of women within fisher households—through forms of employment ranging from handicrafts to poultry keeping, to net making—enabled by either governmental or NGO activities—must be considered as part of the overall pattern of social resilience within the community.

Integration of Fisher's Local Ecological Knowledge. Fisheries are complex SESs, and thus fishers' local ecological knowledge, experience, observations, and opinions should be integrated into fishery management policies and the implementation of those policies. The present study revealed that hilsa fishers have immense local knowledge concerning hilsa's breeding periods, feeding habits, fishing ground, and migration patterns. As an example, such knowledge may help set the dates for hilsa fishing ban periods and the geographical boundaries for fish sanctuaries and in formulating other fishery policies.

5.3. Limitations and Strengths

Throughout the process of carrying out this research and writing the dissertation, I have come across several limitations and strengths that are necessary to highlight. The first limitation is the small number of respondents, which may have created validity issues for this study; however, given the study's qualitative nature, the quality of the data compensates to some extent for the limited sample size. In addition, elaborating on the comparative severity of the presented impacts in the DPSIR framework helps strengthen the present study.

Second, the use of qualitative methods enabled the collation of in-depth perspectives on the values held by the respondents. Many of these respondents attempted to justify the power asymmetries in their societies, their pursuit of a more significant share of local decision-making powers, and their illegal and unsustainable fishing practices. How broadly these attitudes are shared in the larger population is difficult to determine because of the relatively small sample size involved in this sort of study.

Third, this study focused mainly on household and community scale. Considering the intra-household variability may provide some new insights into the SER of fishing communities. Broader range (more coastal districts including all the six hilsa sanctuaries in Bangladesh) studies on these issues may help generalize the findings.

The main weakness of this study concerns my sampling strategy. It would have been standard to employ a wider variety of research methodologies (both qualitative and quantitative/mixed methods) with the same group of people. Quantitative analysis of the interview material could have also been interesting. For example, selection of clusters and subjects could have been backed up by

a frequency analysis of works and issues mentioned during the interview. In such a way, I could have matched all the collected socio-economic data to the qualitative data and made more robust conclusions. However, because of logistical limitations and the continual nature of my research method application, I was not able to employ that approach.

In this dissertation, I used the qualitative case study approach, which ensured the issue is explored through a variety of lenses. This strategy allows for multiple facets of the phenomenon to be revealed and understood. Besides, I chose to follow a qualitative methodology because it enabled me to consider my interviewees' various areas of expertise more flexibly. I believe this has been one of the significant strengths of the present study. I ended up obtaining a much broader understanding of the SER of hilsa fishing communities instead of just gathering the perceptions of a smaller group of participants.

Although this study focused on four coastal fishing villages of Bangladesh, the results are potentially applicable across a broader context, and not only in coastal artisanal fisheries. While the study focuses on Bangladesh's hilsa fishery, the operationalization of the SES, DPSIR, SER, co-management, and power cube frameworks, as demonstrated in this dissertation, can also be applied in other studies to reveal subtle ways in which biological and sociological dynamics intertwine, how asymmetrical power relations are manifested, and how broader-based participation can improve sustainability in the realities of local communities and actors who consume and are dependent on the same natural resources.

5.4. Future Research

While carrying out this research, and particularly in drawing my conclusions, I identified several important issues and questions that call for further investigation. First, the DPSIR framework in this study requires future work that should include follow-up for its development as a decision support tool for fishery management. Given that I identified more than 10 plausible responses, it could be constructive to assess which responses support or contradict each other. Forthcoming research could also assess possible synergies and incompatibilities between responses in the DPSIR framework depending on the surrounding societal trends and realities. Second, a set of social resilience characteristics that are essential and common across global fishing community contexts needs to be identified to develop a generic social resilience framework. However, further investigation is necessary to create such a generic framework. Third, this study revealed that there are power asymmetries in hilsa fishery governance among the stakeholders. Many of these respondents attempted to justify the power

asymmetries in their societies, their pursuit of a more significant share of local decision-making powers, and their illegal and unsustainable fishing practices. How broadly these attitudes are shared in a wider population is difficult to determine because of the relatively small sample size involved in this study. Further research would thus be needed to subject the findings of the present study to a more robust quantitative methodology.

Another important issue raised during the interviews and FGDs—the need to find solutions to free hilsa fishers from the debt cycle created by local money lenders—requires empirical research. Furthermore, the social-ecological trap lens has not been used to date in the Bangladeshi SSF setting, including hilsa fishery, despite its value in addressing how fishers' experiences with poverty diminish their capacities to adapt to, or identify with, additional or alternative means or sources of livelihood. This is especially important in SESs like hilsa fishery because livelihood options and—given weak or missing regulatory institutions—choices may well intensify local community dependence on fishery and lead to overexploitation and eventual fishery alterations. Finally, research also needs to look at how the implications suggested in this study fit into the broader development arena. For example, this study highlighted a transboundary initiative by India, Bangladesh, and Myanmar for the sustainability of hilsa fishery, because hilsa is harvested in the Bay of Bengal by fishers from all three countries. However, more studies are needed at multiple scales to understand better how to initiate and implement the transboundary initiatives, including how to carry out joint fishing bans and to enforce these across all three countries simultaneously.

5.5. Final Remarks

Hilsa fishery involves multiple stakeholders. Their participation is crucial in implementing, monitoring, and enforcing regulations that can lead to compliance through collective action and can work well with institutions, incentives, and compensation schemes. Furthermore, the lack of proper policy implementation, participation of the local communities, and institutional collaborations has led to ineffective hilsa fishery management in Bangladesh. The timely enforcement of the policy, supported by close cooperation between relevant governmental institutions and local communities, is crucial for the sustainability of hilsa fishery. Given that hilsa is a transboundary species, good practices that can be established in Bangladesh can also serve as benchmarks for programs in other countries with similar contexts. The results of this dissertation demonstrate the intricate links between ecological and social resilience. Based on my initial findings, I propose the establishment of co-management in hilsa sanctuary areas;

this approach has vast potential for enhancing both the social and ecological resilience of hilsa fishery.

I close by sharing a quote by a veteran hilsa fisher in study area 2, hoping that policymakers may receive his message and take steps to enhance the socio-ecological resilience of hilsa fishery:

We cannot think of a single day without hilsa. Hilsa is our life and our pride. If we fail to go fishing even for a day, we feel suffocated. We know that we are harming ourselves by catching jatka and broodstock during the ban period. You know we are doing so only for surviving, not for greediness. We just want to live a simple life; we need only to wear simple clothes, eat rice [in Bengali, mota kapor mota vath], and a shelter to sleep. However, we fail to manage our minimum needs, though we work hard to catch fish during the dark of the night, scorching day time, even in bad weather. We all want to keep hilsa sustainable for ourselves and our family members. Also, we want to get rid of poverty; we want to get rid of the debt cycle … Can you pass this information to the government?

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